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Psychological Review

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THE PSYCHOLOGICAL REVIEW

THE SELF AND MENTAL PHENOMENA

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The study of any subject matter may be approached from a variety of standpoints. Each inquiry is guided by a specific purpose which determines the conception of its data as well as the nature of the conclusions to which it leads. This multiplicity of viewpoints is the source of errors which must be guarded against in discussions of the methodological postulates and limits of any science. In the history of psychology a notorious instance of the failure to observe these logical distinctions is to be found in the confusion of metaphysics and descriptive science which underlies the procedure of rational psychology. In contemporary discussion the conception of data and criteria is exposed to error from a similar interpenetration of principles.

The mental life may be considered from three points of view, the practical, the scientific and the philosophical. The first inquires concerning the immediate uses and direction of the mind, the second concerning its structure and development, the third concerning its metaphysical significance. The practical student views mind as an instrument, the scientific as a phenomenon, the philosophical as a real. The first is interested in its external relations, to things and other individual minds conceived as ends of the practical intelligence; the second is interested in its internal relations, conceiving it as an organic system having a typical form of activity; the third is interested in its relation with ultimate reality and inquiries concerning its place in the universe as a whole.

For practical purposes the individual mind is plastic material to be moulded in adaptation to an end; for the scientific it is a class of phenomena to be understood in terms of reciprocal relationship; for the philosopher it is a system of rational activities and ideal purposes to be interpreted in terms of their absolute values. The points of view and aims, the methods of treatment and resultant products, are unique in each of these several ways of regarding the mental life.

In one sense the practical man is not interested in the study of mind at all. His object lies wholly beyond its circle in some change which is to be brought about in the external world. He wishes to sell his merchandise, to obtain good service, to modify social judgment, to secure political victory, or the like. In the attainment of some practical ends other human minds are not involved in any direct way. One deals only with physical materials, as in raising vegetables or making a chair. But in most of the things at which one aims other human wills must be considered. The end is to be attained only through their mediation. One needs their assistance or must overcome their objections,—that is, they appear as necessary instruments or as accidental obstacles to the accomplishment of a purpose. They are to be informed, taught, trained, encouraged, assisted; or they must be persuaded, convinced, circumvented or defeated.

In all their more significant forms our ideals are thus incarnated through the mediation of other human wills. The character of these wills must therefore be considered in our plans. To misunderstand them involves failure because our object can be attained only by allying, transforming or overcoming them. Though we may have no interest in these minds as such, either as systems of phenomena or as purposeful and idealizing selves, yet we must take them into account in our reactions; and thus to take them into account involves understanding them. We must apprehend both the present point of view of the mind with which we deal and its permanent habits of thought and feeling, if it is to be successfully directed or utilized in the furtherance of our aims. A knowledge of men, we say, is essential to success in the world f affairs.

In acquiring this knowledge attention, nevertheless, is not turned to the mind involved but to the end to be attained, as the fencer gains skill not by regarding sensations and movements in the arm which is lunging or making a parry, but through fixing his eye upon that of his adversary and countering or responding to each motion he makes. The mind is not first studied in isolation and the principles thus acquired applied in subsequent dealings with it. Knowledge springs from actual conflict with other minds in the pursuit of the ordinary business of life. While it thus becomes necessary to study these minds, the examination must be carried on as part of the conflict itself. It is a study determined, as to its form, by the requirements of the moment, and as to its degree, by the significance of the practical motive which prompts it. Such knowledge is never an isolated system of truth but in its very origin and interpretation is unified with a system of ends. Never abstract, seldom formulated and then only in a proverb, practical knowledge represents from the outset an essential unity of understanding and application, of knowledge and purpose.

On the other hand, in so far as each moment is dominated by a specific practical demand, there will be studied only that feature of the mind which has significance for this ulterior purpose; and as progress is made toward its realization the characteristics of mind which come into review may shift in a wholly illogical manner. Thus no opportunity is afforded to develop any characteristic systematically in its relation to the rest; no leisure, in the pursuit of practical purposes, to undertake a rational study of the mind as a whole or of any individual aspect or function of it. Practical experience gives a series of vivid impressions of the minds we encounter but no systematic knowledge of their structure. It requires alertness, shrewdness, a capacity for swift intuition of the mental attitude and its bearing upon the matter in hand; and it tends to the cultivation of a mind full of useful maxims, vigilant, retentive of impressions and instinctively wise in the conduct of affairs. For adaptation turns not upon a consistent view of human nature but upon specific informa-

tion and the ability to respond with a definite reaction to each situation as it arises.

The knowledge gained through active participation in experience as a system of ideals and materials for their realization—the education of life, as we call it—has both excellences and defects characteristics of its origin. It is a knowledge won through activity and determined by utility, but it is essentially fragmentary and unsystematic. Practical knowledge of the mind is not the outcome of a consistent attempt to understand the phenomena with which it deals as a whole. In the last analysis, therefore, it provides an insufficient basis for even that practical reaction which it served originally to make possible. Its content is made up of those individual items of information which have been found useful in the attainment of practical aims.

There is a conception of the mind, likewise to be included within this first category, in which the treatment is not instrumental to an extrinsic aim but regards the mind as an end in itself. It is that form of study which is involved in educative discipline and direction. Here, then, is an instance in which it would seem that interest centers in the mind as such, and that the latter may be called the immediate object of study. In this case the essential assumption is indeed the significance of the mind's development as the subject of experience. The training of the mind may be called a means to an end, but its discipline and culture are not of this nature. They rest upon the conception of personality as a subject of worth in itself, though they may involve other things as well, such as the functional contribution of the individual to a system of social ends. Educational interest may thus be said to center in the nature of the mind itself and to seek nothing beyond that mind in its study.

Nevertheless the locus of interest in education lies not in understanding the mind but in developing it, in bringing it to its full realization. The determining conception is to be found in that ideal system of functions and attitudes which the fostering intelligence seeks to develop. The mind as it comes under review by the educator, whether parent, teacher

or priest, is thus conceived in relation to an ulterior reality; and its study is, after all, instrumental to the purpose of attaining a practical end. In neither utilitarian nor educational attitudes is the system of mental processes as such the object—the final object—of study.

In the scientific treatment of mind it is just that complex of phenomena as presented to observation which is under consideration. In its view the individual mind is neither something to be reacted to and made use of in the give and take of vital experience, nor is it a reality which must have place and significance in the sum of things. The scientist is concerned neither with utilitarian modifications of the mind, nor with its ideal valuation, nor with the metaphysical interpretation of its existence. As subject matter for science it is a system of materials and processes definable in terms of the qualities and forms which they manifest but belonging within the general field of describable relations which phenomena at large present. The aim of the psychologist may then be defined as the explication of the content and form of consciousness as a process in time.

This, however, is not sufficient. The system of regulative conceptions under which mind is to be viewed must take its character from the technical purposes of the scientist and the consequent way in which the object of his study is to be defined. The field of descriptive knowledge is in general that system of intelligibly related fact which we call the world of natural law. On the existence of orderly processes the very possibility of knowledge is founded, for only such a world can be conceived in terms of logical concepts. Anomy, chance, caprice are terms by which we mark the absence of those conditions which make science possible. This representation of the world as a system of orderly phenomena is of course the condition of all rational conduct as well as the prerequisite of intelligibility in the object of knowledge.

Of all the fields to be explored by the scientist there is none in which law holds a more significant place than conscious life. It is the general subjection of its materials to ideal order which gives to human existence its characteristic

form and value. Mental life is a unity of functions. Whether a single attitude be considered or the synthesis of successive experiences, its fundamental quality is to be found in the system of significant activities which it constitutes. The consciousness of any moment, for example, manifests a unity in the midst of its obvious complexity of make-up, which can best be exhibited by contrasting it with the essential discontinuity of two individual minds, however near their approximation in content and environment. Each moment of experience, in the second place, stands in intimate relation with that which precedes and that which follows it. As the content of any moment forms a complex within which no single element can be modified without affecting the character of the experience as a whole and of every element within it, so does the content of each moment enter into a series of mutually modifying complexes. Memory holds this series together in its retrospection and gives an added significance to each event by its reference to the system thus imaginatively reproduced. This series of associated experiences, in the next place, forms a system having connection at each moment with the objective world with which it enters into significant relations both by way of adjustment to its changes and by modification of its course. The adaptation of means to ends which the mental life presents, finally, is the expression of a system of rational purposes and ideals which give to experience that consistency and value in which its significance rests.

Human experience is thus not simply a succession of phenomena, of events in time; it is a unity of functions manifested in an orderly and rational process. The mental life is an expression of ideals of law and order. Continuity and rationality appear there as in the system of external phenomena. The relation of order and law to the content which is organized under these forms of the mind, is, however, unlike in the two cases. Unity and rationality are attributed to the external world; they are experienced in the inner order. The unity of the outer world is either a logical concept or a metaphysical postulate; that of the self is a reality of immediate experience.

The phenomena of the external world appear to us as causally determined events. Whatever aspect of significance they may have necessarily escapes the observer. If there be a world-subject—as the self is a subject—which gives to these phenomena a unity and value, it is at least not a reality for our experience. Such unity as we predicate of the phenomenal world must arise from the synthetic activity of our own minds in construing these events, and it is simply attributed to that world as the logical condition of its existence as a system of phenomena. In other words, it is solely a methodological postulate. The unity which we predicate of the mental life, on the other hand, is not thus logically conceived and referred to a system of elements presented as a mere succession of events in time. Unity is an immediate and indefeasible reality of our experience. It is a fact,—if that of which one is thus immediately aware can be called a fact—whose existence is neither posited nor inferred, but intuited. We may thus say, without reservation: There *is* meaning and rationality, law and unity in the mental life, because we find them there.

The mental life therefore seems to present, in its essential form and value, just those characteristics which must be possessed in order that any subject matter may be susceptible to treatment under the general conceptions of science. Yet it is just in this regard that the scientist finds his way closed; for the limitation imposed by his point of view appears within the fields of physical and mental science alike. The methodological unity in terms of which the external order is construed can never become an object of descriptive science. It is not a fact among facts, a phenomenon which can be isolated and regarded apart from the system of things to which it gives unity; nor is it a relation among things, whether of coëxistence or succession, of cause and effect, of dependence or support; nor is it a law expressing such relations in their most general form. As science deals only with facts and their relations, which it expresses in terms of concepts and laws, the metaphysical unity which is apprehended in connection with our intuition of the external world can never become an object of

scientific treatment. The unitary and significant world which metaphysics postulates necessarily becomes a series of phenomena; this can be formulated only in terms of abstract units of constitution which in turn can give nothing but a system of conceptual laws as its result.

The unity of the mental life, similarly, lies beyond the reach of scientific treatment. It is a reality for which the terms self, I, person and so on, are expressions,—the origin, for each of us of all such rationality as we find reflected in the world of experience. It is this unity of the self which makes every part of life significant and gives it value as a whole. It is in its service that the world of experience arises, that its phenomena are studied and their laws formulated, that its materials are transformed and organized under ideal criteria, that the world is conceived as a rational whole. In this sense of unity and value in experience the self is universally expressed. It functions in every conscious perception and act. To the one it gives rational significance, to the other purpose and meaning. It defines and directs, inspires and energizes, subordinates and organizes. It is the unity in which alone each element of the mental process finds meaning. The self is related to the individual elements of the mental life, and to their sum, as the soul's relation to the body has been expressed: It is all in the whole and all in every part. No mental activity exists which does not manifest it; no analysis of experience will ever bring to light a mental event in which it is not postulated.

This relation must be recognized at the outset. Self and event are elements in a single reality which we call an experience. In abstraction from its correlative neither of these has existence; the experience must exist for a self, the self must be realized in a succession of experiences. It is under the conception of self, in this meaning of the term, that all mental facts are treated. Of floating psychical phenomena, that is, of facts not given to a subject—which we describe by the single word 'experience'—we know nothing. In psychology therefore, as in practical life, the conception of self is the ultimate reference in every individual constituent;

for it expresses the final unity of the system of phenomena with which reflection deals, as in immediate intuition it constitutes the unity of experience in the real subject. But in this sense it is not a phenomenon which can be treated in terms of its relation to others in a common universe of discourse. The self is the *summum genus* of the psychologist, the theoretical concept which expresses the necessity he finds for a common reference in all the phenomena he considers. Every mental fact is the experience of some self, it is part of the context of a mental life. But within this field each experience of the self, as conceived by the psychologist, must become an event in an historically conditional series.

It is in this sense that the term is used when we speak of self-existence as something that can essentially be given in a single experience. I am aware of my own existence, we say; I am conscious of myself; I know myself as a subject over against that with which, as subject, I deal in any moment's experience. These phrases are common and carry an important meaning. For the psychologist, however, it is not their practical or metaphysical value which is to be considered, but solely the nature of the fact which is indicated by them. If the awareness of one's own existence be a phase or element of experience, it should be possible to point to the occasion when it arises and to say what kind of an experience it is in which the self is thus immediately revealed. To this in such a case it is answered that every individual experience reveals it. I can be aware of nothing without being aware, at the same time, of myself as knower; I can suffer no pain and enjoy no pleasure without being conscious of myself as subject: I can desire nothing, seek nothing, regret nothing, without postulating myself as the subject of these attitudes of will. The sense of self accompanies and grounds all experience.

But thus conceived self-consciousness is no longer a fact among facts. It is not an experience which can be differentiated from others and studied psychologically. It is equally given in all experience, yet is not a constituent of experience as is sensation, for instance, or affection. It

cannot be made more clear by dwelling upon it, for it does not rest upon a specific content which may be seized and held before the mind. In short it can only be ascribed as the immediate and irreducible reality which is itself self-existence. If there be anything that is metaphysically simple it is this, the universal form of subjective reality. When used in this way, therefore, the term 'self' means nothing more than is implied in the phrase 'conscious fact'; it is simply the postulation of the self as the formal condition of all mental phenomena.

If the term self be used to stand for the system of related characteristics and activities which psychology studies, it has a meaning and value for that science; if it stand for a specific form of experience which can be pointed out in any individual mental life, it may be approached and studied by psychological methods; but as the universal and necessary ground of reference in all individual experience it does not properly fall within the psychologist's field at all. The barren reassertion, in connection with each fact discussed, that it is the experience of a self adds nothing to its treatment; and the indication of this relation should appear in that preliminary definition of the field of psychology itself which must always be carried in mind but needs no subsequent repetition.

There is one class of cases, however, in which these two points of view meet and the subjective unity of experience is projected into the outer world of discrete phenomena, not as a mere logical postulate for reflection but as an interpretative basis for the practical reactions of the will. The mind of another person, however it may be known or presented to him, is not immediately experienced by me. Neither as a systematic unity nor as a momentary self-feeling is it thus given. What is known, and what alone I can observe, is that variety of physical facts which I call expression, speech, gesture, posture, movement, and so on. They compose a succession of bodily attitudes and reactions, now of one complexion, then of another, now occurring in one relation, then in a different one. My observation of the facts in question —all namely which I have in mind which I speak of the ex-

pression of character—is disconnected, partly because of the intermittency of attention, partly because of the obscurity of many factors of the series. As impressions they contain scarcely a hint of that unity which they possess for my mind when I conceive them as the characteristic expression of a self. They are neither contiguous nor correlated; they occur as discrete happenings; and what is involved is, qualitatively, part of the world of sensible objects. They are not even the *disjecta membra* of a self, such as the events of one's own life would be were one to conceive knowledge of self to be the product of logical reflection upon experience, and not an intuition given in that experience itself. Before we can approach the problem of a self objectively given we must construe each complex physical change in terms of a mental correlate to which we attribute it; we must, in other words, conceive it as the expression of a particular mental attitude. Thus construed we ignore the character of the reaction and deal thenceforth with the subjective attitudes implicated, which we then connect by means of the principle of identity, conceiving the various acts as members of a common system of expressions, the manifestation of a particular self.

The conception of a self, in all such cases, is an interpretative attribution,—though not a reflective formula—by which meaning and unity are given to a diverse and disconnected series of acts. We do not, of course, rest with the postulation of a bare principle of unity, but proceed to reconstruct from these fragmentary data the specific characteristics of the self in question, and even to predict the form of expression to be expected in the future. In all this procedure, though the materials are presented discretely as scattered events and must receive formal unification, the conception of a self in such cases possesses more than a merely regulative value. It is not, as in science, an abstract synthetic formula according to which we unify a specific group of facts. The result, therefore, is not a logical formulation but the predication of a real being. What we do is not to treat events as if they were the expression of a self, but as the manifestation of a self really existing. Logically, in all our dealings with

other human beings the other pole of our relation is such a self or real subject, identical in general character with our own being; though this attitude is never systematically maintained but alternates with a treatment of them as objective or instrumental material.

In the case of one's own experience, no less than in the interpretation of behavior in other men, the concept of self needs definition. The term may denote a unifying principle or a unitary being; it may indicate either the product of logical reflection or the significance of immediate intuition. Concerning its value for descriptive science no question can well be raised. It has been used to denote a conception as indispensable to psychology as the concrete and dramatic representation of individual character is indispensable to our adjustment where the practical reactions of other human beings are concerned. But in the case of each of these two specific contents which the term self may receive we must consider what status and value it possesses in relation to the methodical aims of psychology.

Every event in the mental life may thus be conceived from either of two standpoints,—in terms of its content and relations, and in terms of its form and significance. In the former case it is treated as a phenomenon to be described; in the latter as an experience to be interpreted and appraised. The description of phenomena, as has already been pointed out, is made possible only through their resolution in terms of a constituent unit. The interpretation of experience is necessarily based upon the presupposition of a purposive and rational will in terms of whose ideals it is unified and receives value.

These standpoints cannot be combined in a single intuition. The event must be treated in terms either of its existence or of its worth; no middle course is possible. The two points of view are mutually exclusive, for they represent different purposes and result in products which cannot be compared or brought within the same system. The one point of view is exemplified in theoretical interest, the other in practical and moral activity. The former conceives the

mental event as a problem for the understanding, the latter regards it as an object of the moral or æsthetic will. To conceive the event as a phenomenon is, in general, the point of view of natural science; to regard it as a significant experience in the life of the self is that of the real subject.

Personal experience is intelligible only when conceived in terms of a significant process in which, through reaction upon a conditioning and modifiable world, certain practical and theoretical ideals are realized. The primary aspect of all experience is this rearrangement of its materials in the service of an ideal order. The specific content of any such ideal must be stated in terms of the subject of experience and its demands, whether the organization be practical or sentimental or logical. The forms of organization comprised by the cycle of experience are thus never to be referred to objective determinants, such as the recurrences and juxtapositions which are to be found in their material elements. Every unity of experience reflects the synthesizing activity of the self which is universally originative. To refer it to the unities of the world of physical stimulations is unthinkable.

Our perceptions, in which the phenomena of sense-impression are organized into a system of things, are not to be explained by any analysis of the field of sensation. Their demarcations and combinations cannot be expressed in terms either of the momentary correlate which they possess in the world of sensations, or of the history of its constituents as elements in the past experience of the individual. Whether we consider the qualitative aspect of sensations and the logical resemblances and differences which they present, or the constellations in which they are grouped and the serial interruptions which mark their course, the result is the same; no adequate explanation of the forms of organization which appear in the perceptual world can be found in the connections and sequences which the field of sensations presents.

Memory, similarly, is not a reflection in consciousness of the order of past impressions. Neither its architectonic principles nor its function in individual experience can be referred to the uniformities of coexistence and succession in

the field of stimulation, or to the order of impressions which they occasion. Memory is an originating and selective activity which at each moment reorganizes the materials of past experience in the service of a present demand. It does not represent the content of an earlier moment nor reproduce the actual successions by which experience was originally marked. All memory is synthetic and productive, as well when we recall those phases of past experience which are to be brought into practical relation with the present as when we give new organization to the materials which imagination affords in the service of some logical or æsthetic ideal. The distinction between reproductive and creative types is a discrimination in teleological relations and not in the ultimate nature of the processes involved.

Nor is the system of connections which our thinking presents at any moment to be explained in terms of the so-called laws of association. The web of rational thought is no product of adhesion between contiguous ideas, no result of the frequency with which ideas have recurred together in past experience. As well try to explain the relation of hewn stones in a building by reference to the contiguity of rock-masses in the quarry, or the frequency with which pairs of blocks were laid side by side on the various vehicles which transported them. In proportion, one is tempted to say, as an individual mind is dominated by the historical succession in which its materials have been presented,—by what we call the routine of past experience,—the less will be its unity of theoretical organization and the less its practical efficiency in reaction,—the less, in a word, will it be able to think. These, and all other forms of organization which the mind exhibits, must be referred to a wholly different origin, namely, to the ideals of the self and the system of purposes which its life comprises.

If, therefore, we seek a key to the forms of organization which mark either the momentary or the habitual attitudes of the individual self, it must be sought not in the system of materials presented,—such as the immediate field of sensations and the physical or social milieu in which the subject

lives,—but in his systematic dealings with such materials; in a word it is to be discovered in the characteristic reactions through which the attitudes of the self are expressed. That is a unity, for example, which (however it be made up) I treat as a single thing; and that is dual which I treat in terms of two distinct reactions, whether its constituents be more manifold than the former or less so. As the most generalized form of the self's reaction upon the world is the singling out of a particular complex of elements to be the object of the moment's conscious activity, this might be expressed by saying that that is a unity which is the object of a single act of attention. If we are to seek a specific system of correlatives with which to relate the forms of organization which occur in our experience, it must be in the succession of acts in which we deal with the materials of intuition, not in the character and relations of these materials as originally given in sensation.

But this must not lead us to regard the system of reactions as original any more than the system of impressions. The formal unities which the mind presents are no more the mere reflection into consciousness of the reaction or bodily attitude which the stimulus occasions than they are the product of the physical constitution of the stimulus itself. The latter concept, like the former, eliminates the subject from the equation, and makes mental organization the result of changes in the external world. It is thus wholly unserviceable in the work of interpreting the nature of experience. It makes the self as purely a derivative phenomenon as when we attempt to describe the unities of experience in terms of the materials unified. The reactions in question embody forms of organization under which the self has conceived the materials thus presented; they do not give rise to them. The reactions are derivative, not original; instead of producing they are the result of those formal unities in terms of which the self apprehends or modifies the materials of experience.

It is thus evident both that we must approach the self through the system of reactions which constitutes its response to stimuli and that we must treat these reactions as flowing from, not determining, its character. The arrangement of

materials primarily offered must in the end absolutely fail us here. How the sculptor conceives a block of marble appears in the figure he carves from it, as do the conceptions of builder, painter, roadmaker and geologist in the respective modifications they produce. These characteristic reactions find their typical manifestation in human language, through which alone they can be satisfactorily made known; for all those other embodiments which the mind's unities receive through the organizations of materials are but inadequate approximations. I unify the multitude of plants which a summer field presents when, having studied their characteristics, I arrange them in groups according to principles of classification; but this reaction upon my materials cannot be completely embodied in the grouping of specimens in beds or herbaria. It finds adequate expression only in the botanical system of nomenclature which language makes possible.

The centrality of this conception in all our ideal affairs is beyond dispute. Individual life is the realization through plastic materials of an active self which expresses its nature in characteristic and unitary ways. But the distinction between such a concrete unity as confronts us in this field and that abstract unity which the psychologist seeks needs constantly to be redrawn, just because the former has primacy in experience and the psychologist himself slips only too easily into his habitual way of construing the materials of intuition.

It has been pointed out that any mental event may be treated in terms of either its content and relations or its form and significance; in other words, it may be conceived as a phenomenon to be described or as an experience to be interpreted. This may perhaps be illustrated by developing the latest oppositions in certain unifying concepts which are almost indifferently applied in descriptive psychology. In connection with the following statement it is to be remembered that in formulating such implications one must of necessity go beyond the uses actually made of the concepts in question and may seem to do violence to terminology.

The complexity of the field of consciousness appears under

a two-fold aspect. Quantitatively it is represented in a multiplicity of elements; qualitatively it appears in a diversity of constituents. The numerical complexity of the content of experience is resolved in the concept of association; its qualitative complexity is resolved in the concept of the self. The former is an abstract synthesis of materials, the latter is a concrete unification. The concept of association is the result of generalization from experience,—it is a descriptive formula. The self is a substantial existence, which may be defined as the real subject of experience. The term association thus serves the same purpose as every other abstract concept in psychology; it indicates and unifies a specific system of phenomena. The term self also unifies the content of experience. As each mental state exists only in connection with a modifying system of associates, so the self's experience at any moment is single.

The term quality, as used here, does not refer to those sensory differences which separate the various orders of sensation, visual, auditory, and the like; nor to those which appear within the limits of each several sense and form a series of variations such as hues or tones. These differences are called qualitative, but they serve only to condition numerical distinctions within consciousness. Discrimination turns upon specific sensory differences, call them variations in intensity, vividness, quality, extension, or what one will. Any two things must *be* unlike—whether they are objects in space or events in time—if they are to be distinguished. The specific nature of the difference is inconsequential. The immediately felt sensible unlikeness must be there if the field which is unified in association is to be conceived as numerically complex. This form of qualitative differentiation is but one aspect of the field of consciousness which is quantitatively manifold. Its resolution therefore raises no new problem of unification.

But there is another series of differences, not to be unified in this way, for which the conception of the self or real subject is invoked. The content of experience cannot be reduced to a representative system alone. It is not comprised

in sensation, image and concept with their connections. Thought, if the term be used to describe this aspect of the mental life, is but one of several sides which that life presents. Traditionally its scope has been expressed in terms of three concepts,—cognition, affection and volition; or thought, feeling and will. None of these is pure. Feeling is never blind or passive; thought is never passionless or without result; action is never motiveless or objectless. Each term represents a logical resolution of the moment of experience in terms of a single conception. No one of these elements is chronologically isolable. They do not represent states of mind but aspects of the inner life. The experience of any moment necessarily involves all three constituents.

The coexistence of these qualitatively different phases of mental life raises a new problem of unification. Descriptive formulations fail to meet the situation. The concept of association is inapplicable, for as thus construed these aspects of self-activity are not constituents of a single field of data, such as must be given in connection with the psychological object in all its transformations. They are not temporally dissociable, as are successive events; nor mutually exclusive as are objects in their spatial arrangement; nor subject to logical redistribution as is a series of tones or of concepts. In order to bring these three aspects of the mental life into relation one must turn to the conception of their significance in the unity of functioning which that life presents. In the experience of a self each of these phases has a characteristic place. Feeling gives value to experience; will modifies experience in the service of feeling; thought guides the will in its activity. Out of the domain of feeling arises the system of ideals which the mind possesses; will is the continuous attempt to realize these ideals; thought reveals the world as a system of means by which the ends set by feeling may be attained. That the wish is father to the thought is true in a fuller sense than the proverb intends; for the thought is, pragmatically, a stage of the realization of the desire. It is not simply a thought—a mental representation the significance of which is exhausted in its own inner content—it

is a reconstructive programme, a plan of action which has for its object the re-making of the world in some particular.

Thought is thus indissolubly joined with action on the one side and with feeling on the other. Not only does thinking pass over universally into doing, it is also the necessary condition of action. Happiness does not attend upon the soul like a shadow upon the movement of an object. It may be posited as the soul's ideal state, that in which only it rests; but dissatisfaction with an existing situation does not banish or induce the ideal condition. The soul may be miserable and know no way of escape; as it may be happy—that is, find the state in which it exists ideal or pleasurable—without having striven for its attainment. Happiness and unhappiness describe positive aspects of the concrete consciousness, irrespective of the relations in which it stands to the process of transformation. The discomfort of a toothache is a fact whether one know how to seek relief or not. Even when the representation of the ideal state is possible—as when one has had experience of a happy condition of which he retains remembrance when a state of misery supervenes—the envisagement of the ideal does not make it real. The end sought by the will, in such longing, is not realized by a simple fiat. The situation must be changed by some reaction upon the environment, not by the existence of the inner discontent or desire for another state. There is always something to be done. That quality of consciousness which is represented as ideal is attained only as the consequence of an act or series of acts terminating, objectively, in a changed world. To recognize an objective order and to exist in it means just this. That world is a system of reality which the mind does not create, which does not reflect faithfully the transformations in the individual consciousness—that is, it does not constitute a pure objectification of the self's activities, a world which exists simply in virtue of the appearance in consciousness of a structure of ideas.

At the same time the self finds the objective world plastic to its purposes. It is neither the shadow of subjective movements nor are the latter simply a reflection of its fixed order.

The world is a system of means which conditions the self's realization of its ends; and the modification of the objective system is followed by a transformation of the subjective. The attainment of the whole system of ideal ends which life comprises, whether practical or theoretical, utilitarian or æsthetic, is thus conditioned by the use of materials which the external world affords, and its procedure must be subject to the order which that world manifests. To discover the uses to which materials may be put and to formulate the laws of the natural order is the function of thought. The soul seeks perfection or happiness (whatever name may be applied to its ideal state) by all the means within its power. At the outset of its history these means are lacking; the soul is either unhappy without knowing why and without being able to help itself, or it is happy without referring its happiness to an object which it possesses or an objective condition which affects it. The dependence of its states upon such conditions and the connection between means and end it must learn empirically. This we call the development of experience. The soul must thus both achieve its own happiness and create the means by which this achievement becomes possible. This means is, in a word, knowledge. It is the product of that activity which we call thought.

The development of mental content is thus chiefly an elaboration of the process of thought. It is an increase in the understanding of the world and its relations as a system of means by which the ideals of worth may be realized, the progressive enrichment of the soul's apperception of the world as a synthesis of plastic elements. It is this fact which affords such justification as exists for the unequal distribution of topics in psychological discussion; for the largest constituent of all general works of psychology is cognition in its manifold aspects.

In the unification of feeling, thought and will which is thus achieved the resultant product is of a different order from that which appears in association and its transformations. The latter are all synthesizing concepts which the mind has devised in the course of its attempt to describe subjective

phenomena. Attention, association, memory and the like are not hypostatized and given an objective reference. Each is but a formula by means of which certain observations have been brought together or generalized. They represent the association-complex or historical connections in which the fact exists, and—for the psychologist—nothing more. In the case of the self, conceived as that unity of functioning which gives meaning to the whole system of psychic elements,—which not only assigns its place to feeling, thought and will respectively, but also constitutes the ground of reference in evaluating every specific activity of the mental life—no such descriptive generalization is intended. The self is not an abstraction but a concrete being. Its existence is not conceptual but substantial. It has an objective reference, not simply value for the synthesizing mind. Its essence, in a word, is intuitionally real, not phenomenal.

Conceived in this way the term 'self' does not stand for a system of subjective phenomena, nor are thought, feeling and will empirically related facts in such a system. They are construed solely in terms of value, either through a reassertion of the immediate preferences of vital reaction or on the basis of some specific metaphysical interpretation, as in ontological voluntarism or intellectualism. The constituents of the self, in this meaning of the term, have therefore no status as data for mental science, nor does their unity express those descriptive and genetic relations with which it is concerned. The point of view which psychology represents conforms to the system of general criteria which descriptive science involves. It deals with the world of subjective experience as a system of phenomena, to be described in terms of its elementary constituents or explained through the determination of its historical relations. The necessary abstractions of science reappear in the treatment of all subjective data. In psychology as in the physical and biological sciences only facts and their relations can be considered. The significance of the world, whether objective or subjective, is irreducible in terms of science.

If it be objected that when thus conceived mental states,

singly or in successions and systems, are a mere abstraction, it need only be pointed out that these are such only in the sense that the atom of physical science is an abstraction (not a fact of experience); and that in exactly the same way the conception of a cause is an abstraction, as every concept is and must be an abstraction since every concept is a formulation designed for the purpose of description and nothing else.

Concerning the nature and use of both the ultimate unit and the final unity dispute has arisen, that is, in regard to psychological atomism and the conception of the self; while the formulation and the application of the intermediate series of concepts is a matter of common agreement. But it is to be noted that these are all equally abstractions, the proximate as much as the final. We cannot say sensation is an abstraction but perception a concrete fact of experience, nor may we say association is an abstraction but the self a fact of immediate experience. If therefore any such conception as 'mental state' or 'mental element' is helpful in describing the phenomena of individual experience, it can be no argument against its use to say that it is impossible to point to such states as facts of experience.

Whether physical or mental the aim of science is to formulate a system of laws which shall represent the relations in which facts stand. It is for the purpose of making these connections intelligible and representable that all its concepts have been devised. In every branch scientific procedure depends upon two general classes of concepts, the one of which may be called constituent, the other unifying. The first is the product of analysis, the second of synthesis. The former process is strictly instrumental to the latter; for to define a thing in terms of an element is the necessary preliminary to its expression through a synthetic formula. In these two ways we deal with the content of experience whatever its qualitative character. This procedure has given us, on the one hand, factors, units or elements; and, on the other, relations, laws and systems. Both series of conceptions are indispensable. We conceive the object of reflection in terms of elements and the law of their combination. Each of these is an abstraction

from the intuition in which it is presented. They neither are interpolated in the series of experiences as facts among facts with which reflection is dealing, nor do they exist alongside the latter as an independent system. The content of every object of reflection is thus conceived in terms of certain constituent qualitative elements, and its form is described by means of a synthetic formula which expressed the relation of these elements.

The function of logical conception in the approach to problems of mental phenomena differs in no way from that which it fulfils in the physical and biological sciences. In psychology it is the system of facts of individual experience which is to be studied. To deal with these facts a series of conceptions is indispensable. These conceptions are necessarily abstract, that is, they are not facts of experience but descriptive formulas conceived for the purpose of expressing the relations of phenomena. In psychology, too, as in every science, the procedure of reflection involves those two phases which we call analysis and synthesis. The result is therefore necessarily some kind of element or constitutive unit representing the content, and some kind of law or unifying formula, representing their organization. Both of these terms are relative to the nature of facts involved, and represent all levels of complexity. By element, therefore, one does not mean the ultimate product of analysis but only its proximate outcome; nor by law the final unity which experience presents, but only the organic form of the facts in question. The unities achieved at a given level may themselves become the constituents of a higher unification, and the elements which analysis reveals on one occasion may themselves be subjected to analysis on another. Thus the contents of a sensation-complex constitute the elements which are unified in perception; the content of presentation, together with that of memory, provides those which are unified in apperception; the incident impression or idea and that with which it was previously juxtaposed afford the elements which are expressed in the law of contiguity; the successive events, those which are conceived in terms of causal connection; etc. Whether

it deal with any individual fact in the stream of consciousness, with the unity of any moment, with the permanent features of habit and judgment, or with the total complex which mental life presents, its point of view remains unchanged. Psychology can no more treat an individual fact of experience, as experience, than it can deal with the unity of individual consciousness as a whole. Each is to be expressed, first, in terms of its internal relations. It is conceived as a complex presenting a problem of structure, which is resolved in the concept of a unit of constitution and a formula of organization expressing this system of relations. Each experience, in the second place, is to be conceived as a unit having relations, of dependence, support and the like, with other elements and complexes of phenomena in a larger world, and therefore as presenting a problem of external relations. The determination of this system of relations and its expression in a series of laws is the second task of descriptive psychology. The individual experience is a complex whole, expressive of the functional relation of parts; but it is also a unit in a larger whole made possible through the existence of many individuals in those specific relations which characterize their organization. The self likewise is a complex system expressing in its form the relation of functionally connected elements; but it is also a unit in its reaction upon the external world and in its adaptation to other human wills.

Whether psychology deal with the self, then, or with the individual experience, it must treat its subject-matter as a system of phenomena, expressing its analysis in terms of a unit and its synthesis in terms of a law. In the proper sense it is not the self which is dealt with in any such case, but in the final analysis an individual event alone. The starting-point is the unit of real experience. This unit psychology conceives as a complex phenomenon whose constitution it must ascertain and formulate in a conceptual law. Out of these elementary abstractions is built up a series of concepts of increasing complexity or generality. These constitute the synthetic forms of wider and wider aspects of experience. The psychologist is bound to seek these forms throughout

his whole field, to treat of conception as well as intuition, of reasoning as well as judgment, of character as well as apperception, of adaptation as well as imagination. He must describe the stream of consciousness as a whole and indicate the most general characteristics of the mind just as he must analyze the content of each moment and establish the association-forms in which their elements appear.

The whole mental life is thus the field of psychology, in its grosser features and more permanent relations quite as much as in its minor details and individual characteristics. But while its province is coextensive with mental experience it is still a single continuous field within which only one type of material is to be found, namely mental facts and their relations. The existence of these facts in a single connected system does not constitute a self, if that term be used to describe the unity of the real subject. Psychology does not substitute for the known self a reality of the same order but corrected, rationalized, understood. There is but one unitary process of experience, upon which mental science makes simply an illuminating comment.

If these two meanings of self are to be excluded—if the psychologist is concerned neither with the assessment of immediate values in life nor with the metaphysical interpretation of experience—there remains the question, whether the term is to be excluded or retained and, in the latter case, what meaning is to be given to it. As commonly used it is not free from ambiguity, and within its more technical application there is a merely formal as well as materially important use of it.

In the first place there is a specific meaning which may be given to the term self in psychology as denoting something which the scientist is called upon to study among other particular mental facts. The sense of self is both a recurrent experience and an element of experience, though probably not universally or necessarily. As a recurrent event, while the sense of self-existence may not be an important constituent of experience it is nevertheless a familiar fact. At times, either for practical or theoretical reasons or as the result of

uncontrollable conditions, the self looms up in consciousness and engrosses attention. One is said to be *self-conscious*. The content and connections of such a sense of self vary greatly from occasion to occasion, but the nature of the phenomenon is not obscure and its analysis and explanation involve no conception which the general treatment of psychological data has not already formulated. In such cases there is commonly an interruption of the orderly flow of ideas, a disturbance of both the vasomotor and the voluntary muscle systems, and an intensifying of the affective tone of experience. The ordinary network of sensations, images and reactions is thus replaced by a new and characteristic complex; but while it constitutes a unique and frequently distressing consciousness its make-up as to nature differs in no way from those mental states at large with which the psychologist deals.

As an element of conscious experience at large the sense of self is introspectively discernible in at least its major part and, as a constituent of mental life, may extend beyond the human subject to include the range of brute existence. But in this sense the term means no more than a dim undefined background of feeling which characteristically accompanies presentative and representative experience alike, and resembles more perhaps than anything else the vague sense of familiarity which penetrates our common apprehension of the external world. It is a vital constituent of experience for each one of us, yet little is to be made of it theoretically; it is there, it is to be noted, and that is all.

In the next place the term self has a material application in psychology as indicating the totality of mental characteristics and activities with which that science is concerned. Its field is the mental life, in all its types and modifications, normal and pathological, developmental and degenerative. This system of data,—the field of experience as subjective and individual—reveals, like that of any natural science, an unsuspected complexity of structure and relationship as it is explored. Even the normal self presents a bewildering profusion of idiosyncrasies in individual habit and reaction, in

qualitative make-up and affective tone, under specific stimulation.

When from its original terms in the normal adult self one traces the expansion of psychological interest in every direction, which has taken place in the past generation, and notes even the mere quantitative addition to our knowledge of mental phenomena, the largeness of the task is first dimly apprehended. But one thing at least is forced upon the attention, that in its actual inner variety and in its subtleties of response or rapport the features of the human mind are no more made known in the ordinary course of experience than is the subject-matter of any other science to those who may have to deal with its materials in a practical way.

The work of psychology in all its branches, experimental and theoretical, is directed to the development of that complex conception which reflects the rich and varied life of the mind. This life, complicated beyond representation in its characteristics and activities, subject to modification in its specific features by every incident stimulus and undergoing progressive development with each successive experience, and therefore explicable only in terms of its whole history—this self, as we call it, can no more be given to the subject in an intuition, that is, be realized as an experienced fact, than it can be given to an objective observer. It is presented in any moment's experience only in a certain phase, relation or attitude. It can be known only through the whole succession of experiences which constitutes individual history, for its features are not given a priori but must be learned empirically by the subject as by all others. In its fulness it is the summation of all those individual characteristics which are determined through reaction to specific situations, the occurrence of which depends upon the order of the objective world.

The filling in of this picture is, in general, the task of descriptive psychology, and its subject is commonly called the Self. This empirical application of the term is grounded in popular speech and its use in this connection involves no necessary confusion. Nevertheless the term is not free from

ambiguity—since it is also employed with those other meanings already pointed out—and the psychologist has at his command, in the word 'mind,' another common term which is free from these secondary implications. Especially when the field is extended, in comparative psychology, to include lower forms of life it becomes increasingly apparent that the term 'self' does not express with exactness what the psychologist intends. It is because the term 'mind' carries just this specific reference to the complex of thoughts, feelings and actions which individual experience presents, that it has obtained a secure place in psychological terminology as designating its general field of exploration.

Contrasted with this use is another application of the term 'self' which expresses nothing but the logical limit of reference postulated in the definition of the science itself. The intuitional content of the term has already been discriminated from its scientific application. In the former case we mean by the self the actual subject of experience. When I say: the self is real, I mean thereby to assert only what is implied in the statement: I am. In this sense the self is neither phenomenal nor noumenal, for each of these terms implies a logical resolution of the manifold of experience. Or, it might perhaps be said with equal truth, it is both noumenal and phenomenal, since each of these treatments of reality, if valid, must be true of the self. It has a phenomenal existence, the content of which psychology treats; and it has a noumenal significance with which metaphysics deals. Though neither science nor metaphysics is concerned with the subject of immediate experience, it is the necessary object of reference in all treatment. In psychology it becomes necessary to mark the unity of the whole system of phenomena with which the science deals. In the first place no mental activity exists independently; correlation is everywhere presented. The various mental processes mutually condition, modify and contribute to one another; they form a network of connected functions. In the second place through all the data of psychology runs a qualitative identity which may be characterized by saying that everything the psychologist touches must be

conceived in terms of individual subjective experience; it must either be itself a fact of consciousness or be restatable as a condition or product of consciousness.

Now the term self has been used to denote this unity of materials and relations which must everywhere be assumed but nowhere becomes the object of descriptive treatment. It marks the field within which every inquiry falls. All psychology is the psychology of self, but there is no psychology of selves which may be placed over against what may be called the psychology of the constituents of the self, that is, of the particular individual phenomena of the mental life. For everything which science treats must be conceived in terms of its relations to other things; and while each of the special mental processes exists in a system of functions and thus affords a field for psychological treatment, the same does not hold true of the self.

It cannot be urged that the self must be susceptible to treatment as a unit in a larger system of things since social psychology exists. The latter can be differentiated in no way from individual psychology as regards either the nature of its subject-matter or its general conceptions. It investigates a special group of activities and products falling within the general field of psychological inquiry, namely those which depend upon the fact that man lives in association with his fellows and that this mode of life gives rise to certain communities of thought, feeling and action which do not come into sight so long as one regards the psychological subject from a strictly individual standpoint. But these modifications arise like all others. They appear as reactions upon changes in the external world and introduce no new order of occurrences into the mental life. The only object which is ever before the psychologist is thus some special mental event or process, and his problem invariably is the determination of this activity in relation to the system within which it is found through the establishment of its connections with other individual processes.

ON THE INFLUENCE OF PREVIOUS EXPERIENCE ON PERSONAL EQUATION AND STEADINESS OF JUDGMENT IN THE ESTIMATION OF THE NUMBER OF OBJECTS IN MODERATELY LARGE SAMPLES

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I. Introductory Remarks

In much of the work in which personal equation is a factor the observer is not able to compare his estimates with the true value, and so attempt at each successive observation to profit by his previous experience. If experiments be arranged in which this can be done, the influence of experience upon both personal equation and steadiness of judgment can be studied.

Highly satisfactory materials for such a study are furnished by the data of an earlier paper in which I have shown that there is a pronounced personal equation in the estimation of the numbers of objects in moderately large samples, and have given measures of personal equation and of steadiness of judgment based on the massed statistics of twenty-eight experiments, comprising altogether 15,200 estimates.[1]

In these experiments the errors of observation were recorded in sequence. A group of fifty consecutive estimates with the accompanying determinations of the errors constituted a 'period.' With the exception of a single experiment in which the number of objects was so large that the amount of time required for the counting rendered more than 50 estimates per day undesirable, record sheets for a morning and an afternoon period were filled by each observer.

[1] Harris, J. Arthur, 'Experimental Data on Errors of Judgment in the Estimation of the Number of Objects in Moderately Large Samples, with Special Reference to Personal Equation,' this journal, November 1915, **22**, pp. 490–511.

Each 'period' is for convenience divided into five 'trials' of ten successive estimates each.

In making these estimates each observer made a persistent effort to improve. This was based on a knowledge of the immediately preceding errors and consisted in a constant effort to lay out the desired number of seeds. The constants from the distributions of errors made in the individual experiments were calculated from time to time in the same laboratory, so that the observers had some knowledge of the results of preceding experiments taken as a whole. This knowledge did not, I am quite sure, have any influence upon subsequent experiments.

The main problems involved in the question of experience are two: Is there a change in personal bias as a result of constant effort to improve and opportunity for improvement? Does the judgment become steadier, *i. e.*, does the observer make less erratic estimates, as a result of experience?

Both of these questions are really twofold. Is there an improvement from period to period? Is there an improvement within the period? In short, does the worker improve both from estimate to estimate in the same half daily period and also from period to period?

II. Analysis of Data

Consider first the problem of improvement from period to period.

To test the matter most simply one may merely split an experiment, say our first 700 estimates, into the first and second half, and determine the difference between the constants of the first and second 350 estimates. For personal equation the constants are:

Observer	First 350	Second 350	Difference
Observer *B*.....	+ .120±.164	+ .223±.136	+ .103±.213
Observer *C*.....	+1.331±.159	+ .520±.125	− .811±.202
Observer *D*.....	+2.691±.210	+1.649±.160	−1.043±.264

Observer *C*'s and observer *D*'s personal equations have dropped by an amount four times their probable errors in

passing from the first half to the second half of the experiment. Observer *B*'s has increased by an amount only half its probable error.[1]

For steadiness of judgment the results are:

	First 350	Second 350	Difference
Observer *B*.....	4.552±.116	3.771±.096	− .781±.151
Observer *C*.....	4.408±.112	3.474±.089	− .934±.143
Observer *D*.....	5.837±.149	4.438±.113	−1.399±.187

In all cases there is a distinct and statistically significant decrease in the standard deviation—the judgments becoming less erratic as experience becomes greater.

Instead of contenting oneself with so crude a method as a comparison of the constants for the two halves of an experiment, one may obtain a quantitative expression for the influence of experience by correlating between the number of previous experiences and the measures of personal equation or of steadiness of judgment.

In doing this one must deal with a number of subgroups for each period. It is most convenient to divide each half daily period of 50 estimates into five consecutive 'trials,' each of 10 estimates. For each of these 'trials' the mean personal equation and the standard deviation of the errors must be computed. Thus in obtaining the constants presented here it was first necessary to compute 1,520 means and 1,520 standard deviations, which were then treated as units in computing the correlations.

Since the constant desired is the correlation between the number of previous experiences (or of 'trials') and personal equation and steadiness of judgment, the first period (or 'trial') must be designated as 0 (no previous experience) and the subsequent ones numbered consecutively, beginning with 1.

I consider first the results for the correlation between the number of previous periods of experience and personal equation.

[1] The logical conclusion seems to be that Observer *B*, who at the beginning had practically no personal equation has not changed throughout the work, while Observer *C* and Observer *D* who had distinct personal equations at the beginning have been able to reduce theirs as the result of their experience.

Table I[1] gives the correlation coefficients, r_{pe} with their probable errors and the ratios to their probable errors. The results may also be expressed in terms of the regression of personal equation on periods of previous experience as shown by the straight line equations in Table II., calculated from the formula

$$e = \left(\bar{e} - r_{pe}\frac{\sigma_e}{\sigma_p}\bar{p}\right) + r_{pe}\frac{\sigma_e}{\sigma_p}p,$$

TABLE I

PERIODS OF EXPERIENCE AND PERSONAL EQUATION

Experiment	Observer *B*	r/E_r	Observer *C*	r/E_r	Observer *D*	r/E_r
I.	−.053±.080	−0.66	−.237±.076	−3.12	−.189±.078	−2.42
II.	−.161±.085	−1.89	−.108±.086	−1.25	−.433±.071	−6.10
III.	−.344±.077	−4.47	−.050±.087	−0.57	−.388±.074	−5.24
II.+III.	−.122±.060	−2.03	−.186±.059	−3.15	−.369±.053	−6.96
IV.	+.002±.087	+0.02	+.260±.081	+3.21	−.073±.087	−0.84
V.	−.025±.087	−0.29	−.057±.087	− .66	+.037±.087	+0.43
IV.+V.	−.089±.061	−1.46	+.027±.061	+ .44	+.144±.060	+2.40
VI.	−.017±.151	−0.11	+.353±.132	+2.67	+.078±.150	+0.52
VII.	.....	.....	−.251±.094	−2.67	−.588±.066	−8.91
VIII.	.....	.....	.....	.....	+.114±.086	+1.33
IX.	−.440±.073	−6.02	−.524±.066	−7.94	.....	.....
X.	+.070±.100	+0.70	−.230±.095	−2.42	.....	.....
IX.+X.	−.307±.061	−5.03	−.034±.061	− .55	.....	.....
XI.	−.280±.080	−3.50	−.006±.087	−0.07	+.275±.080	+3.44

TABLE II

REGRESSION OF PERSONAL EQUATION ON PERIODS OF PREVIOUS EXPERIENCE

Experiment	Observer *B*	Observer *C*	Observer *D*
I.	$e=+0.350-.028\,p$	$e=+1.441-.079\,p$	$e=+2.741-.088\,p$
II.	$e=+0.863-.064\,p$	$e=+1.279-.046\,p$	$e=+2.099-.274\,p$
III.	$e=+1.159-.118\,p$	$e=+0.655-.017\,p$	$e=+1.234-.291\,p$
II.+III.	$e=+0.771-.023\,p$	$e=+1.217-.037\,p$	$e=+1.611-.130\,p$
IV.	$e=+0.778+.001\,p$	$e=+0.096+.172\,p$	$e=+0.182-.072\,p$
V.	$e=+0.366-.016\,p$	$e=+1.063-.031\,p$	$e=+0.740+.027\,p$
IV.+V.	$e=+0.917-.033\,p$	$e=+0.874+.008\,p$	$e=-0.391+.063\,p$
VI.	$e=+0.904-.066\,p$	$e=+0.082+1.252\,p$	$e=+2.404+.434\,p$
VII.	.....	$e=+0.623-.086\,p$	$e=+2.194-.361\,p$
VIII.	.....	.....	$e=+0.011+.035\,p$
IX.	$e=+1.450-.129\,p$	$e=+0.737-.159\,p$	.....
X.	$e=+0.348+.021\,p$	$e=+0.411-.061\,p$	.....
IX.+X.	$e=+1.085-.047\,p$	$e=+0.090-.005\,p$	.....
XI.	$e=+0.791-.111\,p$	$e=+0.232-.002\,p$	$e=-0.617+.174\,p$

[1] On general principles I feel that it is highly desirable to publish the original data from which all statistical constants are deduced. In the present case, however, it seems quite out of the question to print the 128 correlation tables upon which the conclusions of this paper are based.

where e = personal equation, p = periods of previous experience, the bars denote the means of the two characters and the sigmas their standard deviations. In these equations

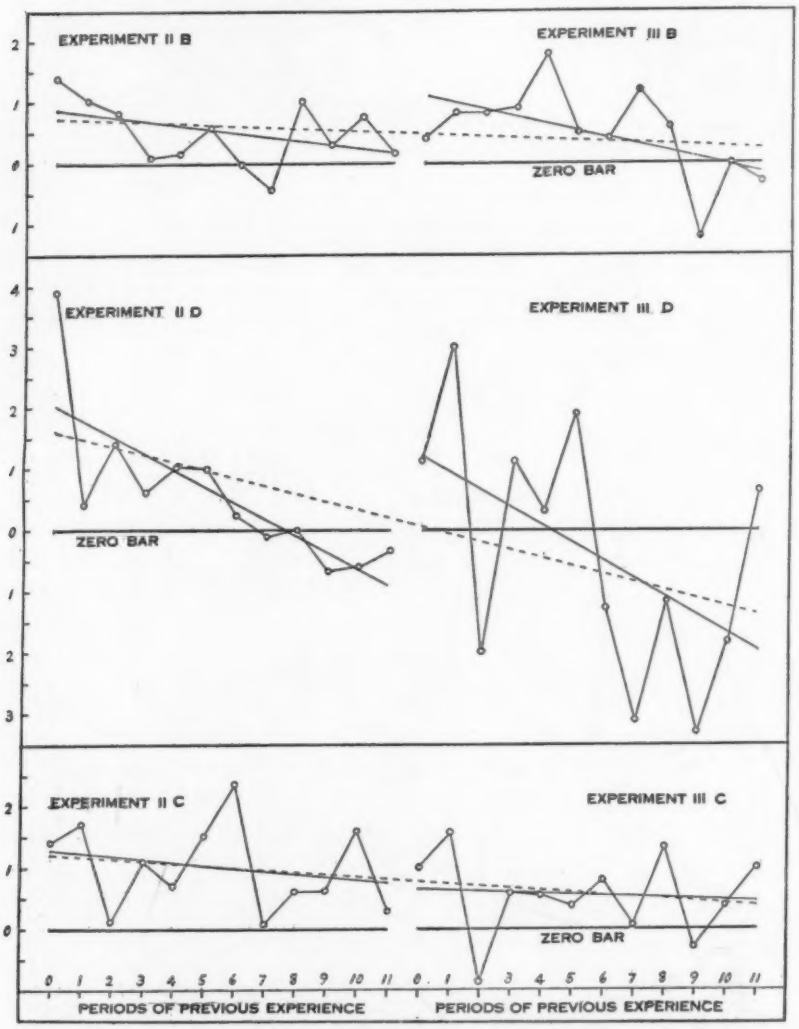

DIAGRAM I. Mean Personal Equation for the Successive Periods of an Experiment. The position of the circles indicates on the scale to the left the mean personal equation for the period. The solid lines represent the regression equations for the individual experiments. The broken lines represent the straight line equations for the combinations of the two successive experiments.

the second term shows the actual amount of change in personal equation per period of previous experience.

The empirical means (personal equations) for each period

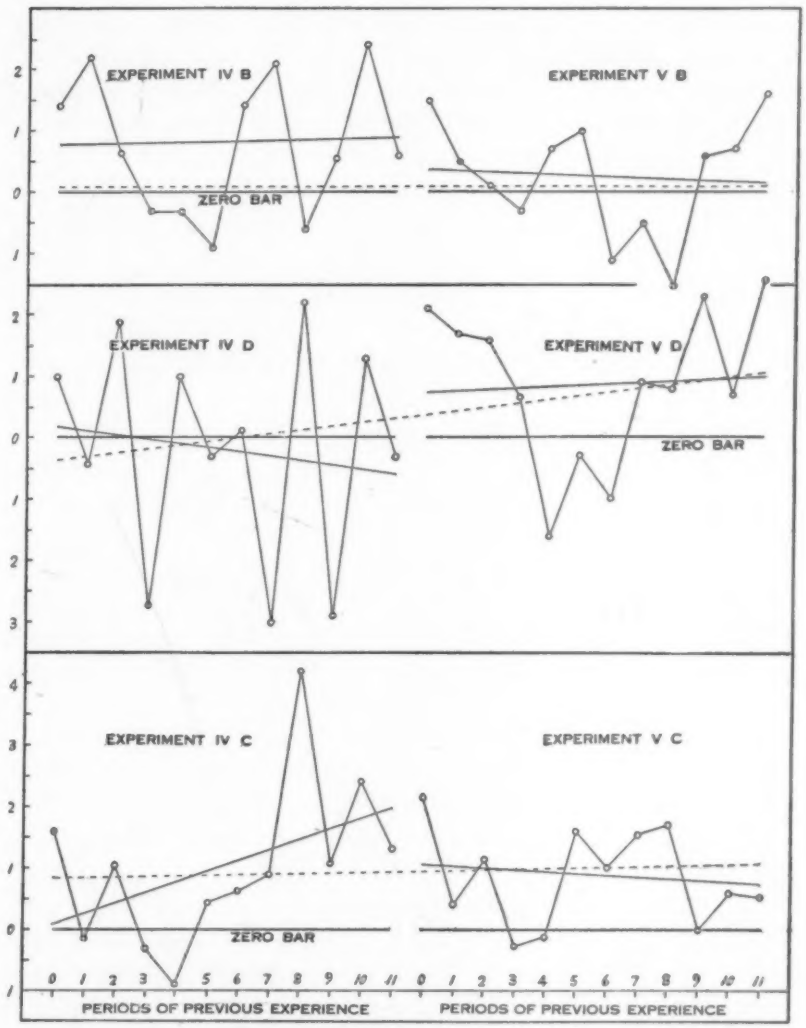

DIAGRAM 2. Explanation as in Diagram 1. Note that personal equation sometimes increases and sometimes decreases with experience. Note that in both cases the means are very irregular but that there is a great preponderance of those on the positive side of the zero bar—*i. e.*, of cases in which the persistence of personal equation is shown in the individual periods.

have already been shown graphically for the first experiment in Fig. 4 of the preceding paper. The lines superimposed upon these are those representing the regression straight line equations. The lines for twelve additional series are shown in Fig. 1-2. These are for the experiments belonging to sets II.-III. and IV.-V., which were made in consecutive weeks. Hence they are so drawn that the regression line (dotted) for the combined experiment may be drawn through the same set of empirical means.

These diagrams may suggest that personal equation tends to become somewhat less pronounced with experience. There are, however, conspicuous exceptions. They show great irregularity in the distribution of the means of the personal equation of individual periods. There is no evidence that taken as a whole these irregular means could be better represented by a curve of a higher order than by a straight line.

The diagrams further show not only that the individuals differ in their mean personal equation from period to period, but that in the case of consecutive experiments the whole trend of the experiments may differ sensibly.

Turning to the numerical values as a means to finer analysis, it appears that in 20 cases the correlation is negative as compared with 8 cases in which it is positive in sign. Of the 8 correlations involving the data of two consecutive experiments 6 are negative and 2 are positive in sign. Experience tends generally, therefore, to change personal equation in the negative direction. Since the personal equations of the observers who took part in these experiments were for the most part of the positive sort, experience leads on the whole to an improvement of the estimates in so far as personal equation is concerned.

In the case of Experiment *C* IX. both personal equation and correlation are negative. The tendency is therefore for the observer to become worse by experience. The same is true in the case of *D* III. and *D* IV.

Thus in so far as the constants may be classified by the signs of the personal equations and of the correlations, there are $8+3 = 11$ cases in which the personal equation tends to

grow worse with experience to 20 − 3 = 17 cases in which it tends to become better. This means that if one calculated the personal equation at the *beginning* and at the *end* of the whole experiment from a straight line equation fitted to the means *of the whole experiment* he would find that in 17 cases the calculated personal equation at the end of the periods of experience would be nearer zero than that at the beginning, whereas in 11 cases the reverse would be true. This point may be easily verified from the equations given.

Averaging the constants for the three individual observers I find, regarding signs,

	Mean Correlation.
Observer *B*	−.136
Observer *C*	−.085
Observer *D*	−.130

For the whole 28 experiments the results are:

	Mean Correlation.
Eight positive coefficients	+.151
Twenty negative coefficients	−.223
All twenty-eight determinations	−.116

If one considers that the three cases in which a negative correlation is associated with a negative personal equation should be classed with the cases in which personal equation tends to become larger with experience the results are:

For 17 cases with tendency to decrease personal equation	−.204
For 11 cases with tendency to increase personal equation	+.199

An examination of these coefficients in their relation to their probable error shows that only 14 out of the 28 are at least twice as large as their criterion of trustworthiness. Of these, 3 are positive and 11 are negative. In two of these cases, however, *i. e.*, *C* IX. and *D* III., the negative sign of the correlation coefficient indicates an increase in the numerical magnitude of personal equation as a result of experience. Hence the statistically significant coefficients—where by statistically significant one means a coefficient at least twice as large as its probable error—stand in the ratio of 11 − 2 = 9 to 3 + 2 = 5 in evidence of a modification in the direction of betterment of personal equation by experience. Thus taken as a whole these data perhaps show a slight but distinct

tendency for the observers to reduce their personal equation by a persistent effort to improve and the constant opportunity for improvement afforded by a knowledge of the amount of error of each estimate made. Improvement by modification of personal equation is however, if it exists at all, very slight.

These findings are in good accord with the results for personal equation presented in the preceding paper, *i. e.*, the demonstration of its persistence in each of the three observers throughout a period of two years.

Turn now from the question of improvement as a result of experience from period to period to the problem of improvement within the period.

Each period of 50 estimates has been split up into 5 trials of 10 errors each, and the personal equation (*i. e.*, the mean deviation) and the standard deviation for each of these computed. These trials are now classified not by the sequence of the periods of experimentation but by first to fifth trial within the periods. In determining the correlation between the number of previous trials and personal equation the first must be ranked as 0 (no previous trials) and the subsequent ones as 1 to 4.

TABLE III

TRIALS WITHIN THE PERIOD AND PERSONAL EQUATION

Experiment	Observer *B*	r/E_r	Observer *C*	r/E_r	Observer *D*	r/E_r
I.	+.370±.070	+5.29	−.073±.080	−0.90	−.002±.081	−0.03
II.	+.214±.083	+2.58	+.234±.082	+2.85	−.329±.078	−4.21
III.	+.193±.084	+2.30	−.074±.087	−0.85	−.150±.085	−1.76
IV.	+.252±.082	+3.07	−.103±.086	−1.20	−.062±.087	−0.71
V.	+.160±.085	+1.88	−.229±.083	−2.76	+.207±.083	+2.49
VI.	−.093±.150	−0.62	−.088±.150	−0.59	−.233±.143	−1.63
VII.	.....	.....	+.110±.099	+1.11	−.240±.095	−2.53
VIII.	.....	.....	.....	.....	+.377±.075	+5.03
IX.	+.140±.089	+1.57	+.001±.091	+0.01	.....	.....
X.	−.191±.097	−1.97	−.025±.101	− .25	.....	.....
XI.	+.170±.085	+2.00	−.194±.084	−2.31	−.111±.086	−1.29

The results are given in Table III. Of the 28 constants 12 are positive and 16 negative in sign. In all cases in which personal equation is positive the negative correlations may be looked upon as indicating a tendency to improvement, whereas in all cases in which personal equation is negative the positive correlations may be taken to indicate improvement. Judged

by this standard two of the negative coefficients *D*, III. and *D* IV., indicate (if they may be considered statistically trustworthy) a tendency to become worse with experience. In the third case of negative personal equation, *C* IX., the correlation is positive in sign.[1] Hence, viewed from the standpoint of progress in the direction of the elimination of personal equations as the result of successive trials of ten attempts each within the individual experimentation periods the results stand 15 : 13, in favor of an improvement within the period.

Only 11 of the 28 constants are two or more times as large as their probable errors. Of these 8 are positive and 3 are negative in sign.

The averages, regarding signs, are:

	Mean Correlation.
Observer *B*	+.135
Observer *C*	−.034
Observer *D*	−.060

The mean of the 12 positive coefficients is + .202, that of the 16 negative ones − .131, that for all the experiments + .012.

The results, extensive as they are, indicate very clearly by the low magnitude of the correlations and their nearly equal distribution into positive and negative values that there is no appreciable change in personal equation as a result of an effort to improve within a period of 50 trials.

I now turn to a consideration of the relationship between the number of periods of previous experience and steadiness of judgment as measured by its standard deviation. The correlation coefficients with the means of estimating their statistical trustworthiness are given in Table IV. The evaluations of

$$s = \left(\bar{s} - r_{ps}\frac{\sigma_s}{\sigma_p}\bar{p}\right) + r_{ps}\frac{\sigma_s}{\sigma_p}p,$$

where s = steadiness of judgment as measured by the standard deviation and the other symbols have their usual significance, are given in Table V.

[1] Neither of the three constants, *D* III., *D* IV., nor *C* IX., can safely be regarded as trustworthy in comparison with its probable error.

The straight lines for the first experiment covering 14 periods are shown with their empirical means in Diagram 3. The means and fitted lines for the two sets of experiments which were made in consecutive weeks are shown in Diagrams 4–5.

Table IV

For Periods of Experience and Steadiness of Judgment

Experiment	Observer *B*	r/E_r	Observer *C*	r/E_r	Observer *D*	r/E_r
I.	−.457±.064	−7.14	−.347±.071	−4.89	−.474±.063	−7.52
II.	−.305±.079	−3.86	−.263±.081	−3.25	−.434±.071	−6.11
III.	−.074±.087	− .85	−.013±.087	−0.15	+.022±.087	+ .25
II.+III.	−.420±.051	−8.28	−.263±.057	−4.61	−.319±.055	−5.80
IV.	−.340±.077	−4.42	−.290±.080	−3.63	−.240±.082	−2.93
V.	−.068±.087	−0.78	−.411±.072	−5.71	−.084±.087	− .97
IV.+V.	−.431±.050	−8.62	−.468±.048	−9.75	−.265±.057	−4.65
VI.	−.337±.134	−2.51	−.311±.136	−2.29	−.628±.091	−6.90
VII.	.....	.....	−.258±.094	−2.74	−.451±.080	−5.64
VIII.	.....	.....	.....	.....	−.037±.087	− .43
IX.	−.244±.086	−2.84	−.095±.090	−1.06	.....	.....
X.	+.220±.096	+2.29	−.244±.095	−2.57	.....	.....
IX.+X.	−.284±.062	−4.58	−.348±.059	−5.90	.....	.....
XI.	−.086±.086	−1.00	−.160±.085	−1.88	−.247±.082	−3.01

Table V

Regression of Standard Deviation Measuring Steadiness of Judgment on Periods of Previous Experience

Experiment	Observer *B*	Observer *C*	Observer *D*
I.	$s = 4.190 - .106\,p$	$s = 4.350 - .087\,p$	$s = 5.770 - .175\,p$
II.	$s = 3.577 - .076\,p$	$s = 3.743 - .078\,p$	$s = 4.480 - .157\,p$
III.	$s = 2.609 - .014\,p$	$s = 2.927 - .003\,p$	$s = 3.069 + .006\,p$
II.+III.	$s = 3.424 - .050\,p$	$s = 3.518 - .035\,p$	$s = 3.948 - .051\,p$
IV.	$s = 6.784 - .140\,p$	$s = 7.402 - .164\,p$	$s = 7.325 - .170\,p$
V.	$s = 5.027 - .025\,p$	$s = 6.059 - .153\,p$	$s = 5.721 - .039\,p$
IV.+V.	$s = 6.500 - .091\,p$	$s = 7.237 - .120\,p$	$s = 6.883 - .081\,p$
VI.	$s = 14.755 - .959\,p$	$s = 13.808 - .951\,p$	$s = 17.770 - 2.278\,p$
VII.	.....	$s = 1.836 - .039\,p$	$s = 3.109 - .161\,p$
VIII.	.....	.....	$s = 2.008 - .006\,p$
IX.	$s = 2.275 - .038\,p$	$s = 1.817 - .010\,p$	.....
X.	$s = 1.666 + .035\,p$	$s = 1.663 - .034\,p$	.....
IX.+X.	$s = 2.184 - .024\,p$	$s = 1.872 - .023\,p$	.....
XI.	$s = 2.959 - .019\,p$	$s = 3.010 - .037\,p$	$s = 4.565 - .079\,p$

In all of these diagrams the straight lines are fitted to the mean standard deviations for the individual trials of which 5, comprising 10 observations each, constitute a period. These means are represented by circles, connected by solid lines. As a check, and to show the influence of differentiation among

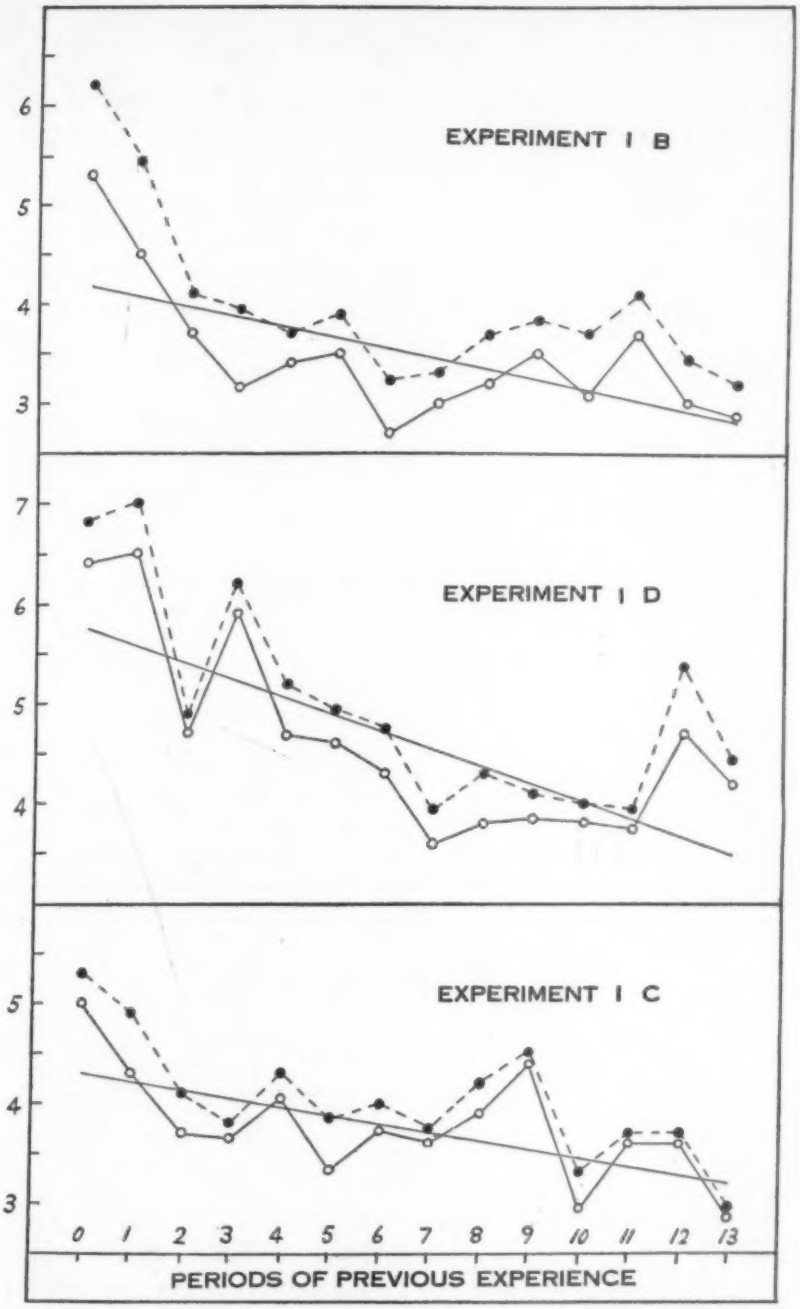

DIAGRAM 3. Means of Five Standard Deviations in the Fourteen Periods of the First Experiments, Circles and Solid Lines, with the Fitted Regression Straight Lines. The solid dots connected by broken lines show the standard deviations for the fifty errors in each period.

the individual trials of a period the standard deviations of the 50 estimates of each period are shown by solid dots connected by broken lines in the first two of these diagrams.

In all cases the constant based on the 50 observations is higher than the mean of that of the 5 sub-groups of 10 constituting the period. This is to be expected from the fact that

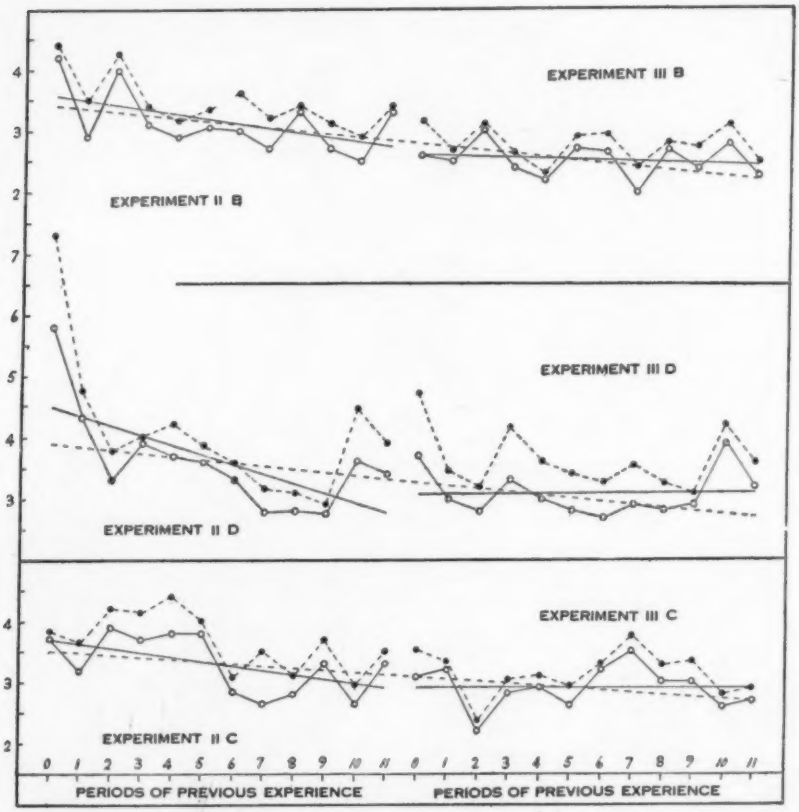

DIAGRAM 4. Explanation as in Diagram 3. The dotted regression lines show the rate of change, if considered linear, for the two consecutive experiments.

the individual trials of a period differ somewhat among themselves. These differences naturally contribute to the period standard deviation when the data of all the trials are thrown together.

These diagrams show something of the amount of change

occurring in steadiness of judgment as a consequence of previous experience. There is perhaps a slight suggestion of non-linearity. At first the standard deviation of the estimates

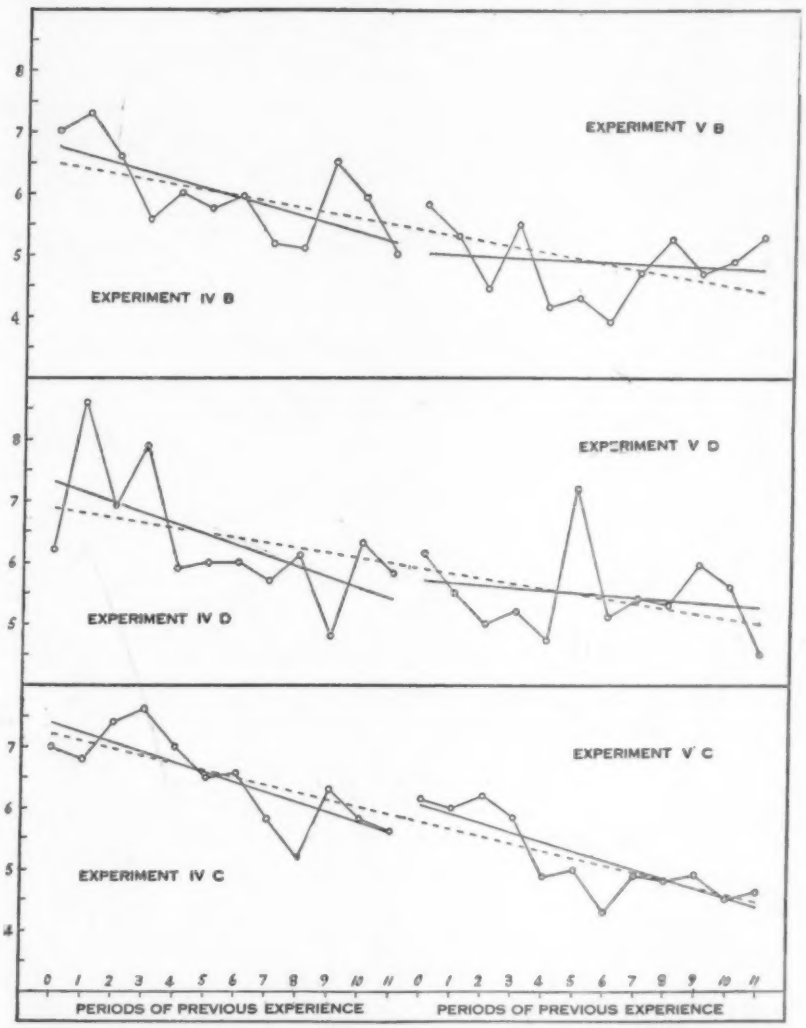

DIAGRAM 5. Explanation as in Diagrams 3–4. The Mean Standard Deviations only are shown.

perhaps falls slightly more rapidly than later. There are, however, cases in which this is not at all apparent. Con-

sidering the irregularity in the empirical means the equation to a straight line represents the change in steadiness of judgment fairly well.

From the table of correlation constants, it appears that *26 out of 28 coefficients are negative in sign.* Thus while personal equation decreases very little with experience as shown by the fact that both positive and negative correlations are found in not widely different numbers, steadiness of judgment unquestionably becomes greater as is indicated by the fact that in practically every experiment the mean standard deviation of the estimates made in the trials of the individual periods decreased as experience increased.

The same point is shown by an examination of the constants in comparison with their probable errors. In the case of the correlation between periods of previous experience and personal equation only 9 constants indicating an improvement in personal equations were at least twice as large as their probable errors. In the relationship here under consideration no less than 18 constants must by the same standards be considered statistically trustworthy. All eight of the correlations covering the range of previous experience afforded by a two weeks' test are *at least* 4.5 times as large as their probable errors, and so unquestionably show an improvement in steadiness of judgment.

The mean correlation for the individual observers are:

	Mean Correlation.
Observer *B*	−.188
Observer *C*	−.239
Observer *D*	−.286

For all observers the averages are:

	Mean Correlation.
Positive values, 2	+.131
Negative values, 26	−.265
All values, 28	−.238

From the problem of the relationship between the number of periods of previous experience and steadiness of judgment one naturally turns to the question of improvement within the individual periods, irrespective of their temporal position in the experiment. Table VI gives the correlation between the

number of trials, each of 10 estimates, and the standard deviation of the errors in the individual trials.

TABLE VI

TRIALS WITHIN THE PERIOD AND STEADINESS OF JUDGMENT

Experiment	Observer *B*	r/E_r	Observer *C*	r/E_r	Observer *D*	r/E_r
I.	−.210±.077	−2.73	−.253±.076	−3.33	−.349±.071	−4.92
II.	−.109±.086	−1.27	−.422±.072	−5.86	−.128±.086	−1.49
III.	−.176±.084	−2.10	−.450±.069	−6.52	+.060±.087	+0.69
IV.	−.319±.078	−4.09	−.408±.073	−5.59	−.005±.087	−0.06
V.	−.234±.082	−2.85	−.294±.080	−3.68	+.013±.087	+0.15
VI.	−.051±.150	−0.34	−.566±.103	−5.50	−.324±.135	−2.40
VII.	.....	.....	+.219±.096	−2.28	−.308±.091	−3.38
VIII.	.....	.....	.....	.....	−.032±.087	−0.37
IX.	−.159±.089	−1.79	−.473±.071	−6.66	.....	.....
X.	−.036±.100	−0.36	−.276±.093	−2.97	.....	.....
XI.	−.125±.086	−1.45	−.385±.074	−5.20	−.013±.087	−0.15

The predominance of negative signs indicates that within the individual periods there is a decrease in the scatter of estimates, or an *increase* in steadiness of judgment. Of the 28 constants all but 3 have the negative sign. The averages are:

	Mean Correlation
Observer *B*	−.158
Observer *C*	−.331
Observer *D*	−.121
All observers	−.208

Of the 28 coefficients 17 are at least twice as large as their probable errors. One of these is positive, the remainder are negative in sign.

For the present it has hardly seemed worth while to calculate the regression equations for this entire series of relationships. For experiment I. they are:

	Regression Straight Line Equations
Observer *B*	$s = 3.779 - .138\,t$
Observer *C*	$s = 4.144 - .181\,t$
Observer *D*	$s = 5.367 - .367\,t$

Diagram 6 shows clearly how great the decrease in scatter of estimates as the result of a few 'trials' is. Apparently too the decrease cannot be satisfactorily represented by the slope of a straight line. The improvement is apparently more rapid at first than later, and some curves of a higher order are required to describe the rate of change.

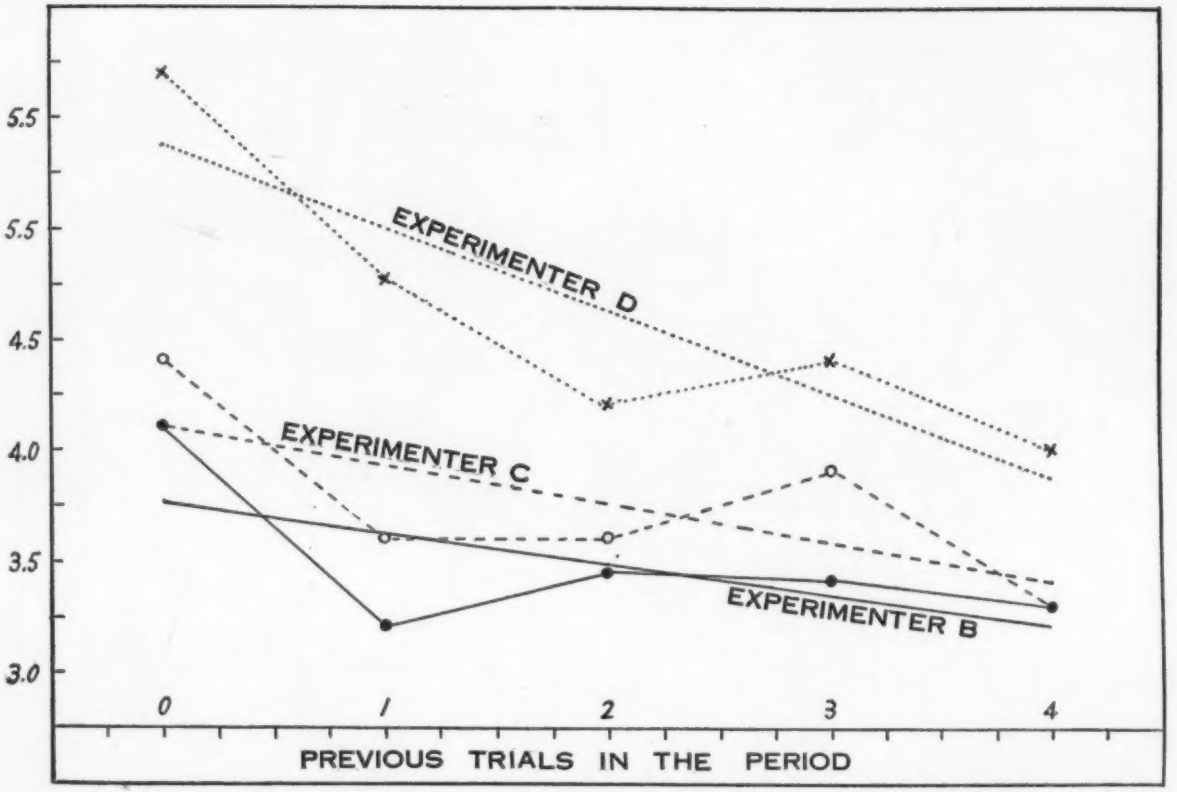

DIAGRAM 6. Mean Standard Deviations and Regression Straight Lines Showing Change in Steadiness of Judgment within the Individual Periods of Experiment I.

To carry this matter one step farther I have calculated the correlation ratios, η, as well as r. They are:

	Coefficient of Correlation	Correlation Ratio
Observer *B*	−.210	.337
Observer *C*	−.253	.364
Observer *D*	−.349	.398

Both of these constants for all of the three observers agree in indicating a real interdependence between the number of previous trials in a period and steadiness of judgment. The signs of the coefficients of correlation show that the estimates become less erratic, or the judgment steadier. The correlation ratio is necessarily positive. Applying Blakeman's test for linearity of regression[1],

	ζ/E_ζ
For Observer *B*	1.75
For Observer *C*	1.74
For Observer *D*	1.88

Thus these mathematical tests furnish no *proof* that the change in steadiness of judgment as the result of experience within the period can be regarded as other than linear. Sometime a detailed investigation of this question for the whole material may be in order, but there seems no advantage in going into it in greater detail at present.

III. Concluding Remarks

The purpose of this paper is the presentation of the results of a statistical analysis of extensive series of experimental data on the influence of previous experience upon errors of judgment in the estimation of the numbers of objects in moderately large samples.

The experiments comprised from 200 to 700 estimates each. These have been grouped for purposes of calculation into ultimate units of ten consecutive estimates each. These are designated as trials. The statistical constants of the errors of the ten estimations constituting a trial are the units of calculation in the present investigation. Five of these units constitute a period of the experiment.

The problems to be solved in a study of the influence of

[1] Blakemann, J., *Biometrika*, Vol. 4, pp. 332–350, 1905.

previous experience are two. Is there a modification of the characters of the estimates as a result of experience from period to period? Is there a modification of the characteristics of the estimates as a result of experience from trial to trial within the period?

The answers to these questions have been expressed in terms of the correlation between the number of previous trials within the period of the number of previous periods of experience within the experiment and personal equation or steadiness of judgment as the case may be.

Personal equation seems to be remarkably little influenced by experience. In some experiments it increases, in others it decreases. Taken as a whole the results indicate a slight reduction in personal equation as a result of experience from period to period. Within the period there is no demonstrable influence of experience upon personal equation.

Steadiness of judgment is in rather conspicuous contrast with personal equation, in that it is unmistakably influenced by previous experience. The correlations between the number of previous trials within the period and steadiness of judgment and between the number of previous periods within the experiment and steadiness of judgment are numerically low, but almost without exception indicate that as experience becomes greater the scatter of the individual estimates about their mean value becomes less. Probably the rate of this change is not uniform, but is most rapid at first and then falls off.

There are a number of points concerning these data which might be discussed in greater detail. My purpose, however, has been to present in outline the matters of fact incidentally brought out in the routine of a biologist's experiments. The detailed discussion involved in comparison and interpretation must be left for the psychologist.

THOUGHT–CONTENT AND FEELING

BY KNIGHT DUNLAP

The Johns Hopkins University

The criticisms which Professor Lovejoy[1] and Professor Bode[2] have made on my paper on Images and Ideas[3] render it my plain duty to give a more extended exposition of certain points in the theory outlined in that paper. I am forced to conclude that these points have not been fully understood; a situation for which of course my condensed statements are responsible. In the present paper, therefore, I shall attempt exposition rather than argument, hoping that by this means later argumentation may be made more profitable.

At the outset I must insist that my whole point of view is determined by distinctions which the conventional psychologist does not make, and that if the reader fails to note these distinctions he will thereby render it impossible for himself to grasp my point. Furthermore, it must be understood that the terms technically employed in my exposition are always strictly used in accordance with a single definition; a practice which the reader may not expect a psychologist to follow.

The first and most important distinction which I ask the reader to note is between *consciousness* and *content*. By consciousness I mean always the awareness of something, whether the awareness of 'present' content or of 'non-present' content. This consciousness may be called by various other names: 'experience' is one of these, but has other meanings also. *Perception* and *thought* I shall use to designate the two sorts or forms of consciousness: *perceiving*

[1] *The Johns Hopkins Circular*, 1914, 3 (March), 42–99. Professor Lovejoy had the advantage over me in that his article, although appearing in the same number with mine, was written after reading mine and discussing it with me.

[2] *Philosophical Review*, 1915, 24, 102–105.

[3] *The Johns Hopkins Circular*, 1914, 3 (March), 25–41.

and *thinking*, together, to designate all that can be included under *being conscious*.

By *content* (of consciousness) I mean anything which can be perceived or thought of: anything, that is, which can be an object of consciousness.

The value of this distinction may be denied. The psychologists in general do deny it explicitly or implicitly, and use their technical terms in such a way as to cover both of the factors which I insist should be distinguished. 'Sensation' as currently used, for example, means both the object observed (*e. g.*, the color blue, the coldness of the skin) and also the observation of this object.[1] *Consciousness* is also used in this double sense. A writer may on one page speak of the blue as consciousness, and on the next page speak of 'being conscious of the blue.'[2]

The validity of the distinction may also be denied. It is usually the case that an individual to whom I suggest this distinction for the first time is unable to grasp it. This difficulty disappears, however, after he has considered the matter for a little time, so that I see no need of an extended discussion of the question of validity. The question of value can be settled only after full consideration. Having carefully observed a distinction, we may in the end abandon

[1] Frequently the term sensation is used by quasi-psychologists to indicate the nerve process; sometimes the schematic nerve process and sometimes the real process. We need not consider these grosser confusions here.

[2] The term consciousness is also used in a great many other senses, to the great confusion and the lasting reproach of psychology. I have pointed out in another place (PSYCHOLOGICAL REVIEW, 1912, **19**, 407–409) that James, in his *Psychology*, applied the term neither to awareness nor content (except a specific sort of introspected content), but to the subject. What I am here discussing as consciousness, James dismissed as the 'mysterious relation of knowing,' with which psychology, according to him, has no concern. James was concerned, from first to last, with the soul, and his whole psychology was an attempt to devise a scheme by which the soul might plausibly be made an object and examined. Misapprehension of James's intentions has led to the most curious consequences in the hands of American psychologists, who have drawn conceptions and phraseology blindly from James, and the term 'consciousness' has become in their hands so meaningless as to be a byword. It is from this reproach that I should like to see the term rescued.

Note.—Since the above was written, Professor Titchener also has explicitly denied that awareness is any business of psychology (*Amer. J. of Psychol.*, Vol. 26, p. 265). What 'consciousness' is, in Professor Titchener's system, I am not able to make out, in view of the different 'levels' or 'lights' which are attributed to it.

it if it proves fruitless; but to abandon it in the beginning is to beg the question completely.

We must not confuse the distinction between *sentiendum*[1] and *stimulus* with the distinction between *consciousness* and *content*.[2] A stimulus is a form of content whose relation to sentienda must be determined somewhere in our psychology, but which cannot be lightly substituted for sentiendum whenever our handling of the latter gets us in a corner. The content blue of which we were speaking above is the observable blue, an object of vision; whereas the stimulus of blue, the ether vibrations, are not visually perceptible, and it is even a question whether they are perceptible at all.[3]

The most important of the questions raised by Professor Lovejoy concerns the question whether consciousness is or is not an observable fact. If consciousness is not observable, how can we assert that it exists? But can you be conscious of consciousness; be aware of awareness; observe observation? Orthodox psychology says that you can. 'Introspection' as defined by orthodox psychologists (not as used by them when the theoretical discussion is over) has been the term for the process in which awareness is aware of itself. It is necessary to recall the two stock difficulties which are supposed to hamper introspection of this kind. In the first place, a conscious state, when introspected, is not the same as it would be if not introspected. You decide, for example, to observe your consciousness of a caterpillar crawling over a leaf. But when you observe this consciousness, you are conscious not only of the caterpillar and his surroundings, but also of your consciousness of the caterpillar. So the consciousness in the moment for which you planned your

[1] Since the word 'sensation' is so hopelessly slippery in its meanings that it cannot be used without serious misunderstanding, however carefully defined, I have abandoned the attempt to use it and will use 'sentiendum' to designate the simple sense-object, sense datum, or sensibile.

[2] This confusion is not a mere formal possibility. I find in discussing the content-consciousness distinction that it is really difficult in certain cases to keep my opponent from shifting over to the sentiendum-stimulus distinction.

[3] It may be argued that the stimulus is an object of thought only; not of perception. Certainly it is not a sentiendum, but is strictly an intellectual content; in other words, it is relational, not sensory.

observation is far different from the consciousness you planned to observe. For simplicity's sake, you may stop here and conclude that the observation of a mental state changes the state itself. For sanity's sake, also, you should stop here, because if you go on to consider that since the consciousness you are conscious of includes the consciousness of that consciousness, it is also the consciousness of the consciousness of the consciousness, and that therefore it is the consciousness of—but that way madness lies. So much for the first great objection to introspection.

To avoid the first objection, psychologists have usually been willing to face a second which they consider less vital. The state of consciousness is never observed at the moment in which it occurs, but is observed retrospectively, *i. e.*, in memory. In a given moment, according to the orthodox psychologist, you are conscious of the caterpillar. This consciousness occurs as a given fact or process, and cannot afterwards be changed or modified any more than any other historical fact; any more, for example, than your falling over a chair can be changed after you have done it. In the next moments you are able to examine *in memory* the former state just as you are able, as you lie on the floor, to recollect how you fell. This theory of introspection courts the objections, first, that since introspection depends on memory it cannot be accurate, and second, and still more embarrassing, that if the conscious state cannot be directly observed, it cannot be remembered, since it appears in general that there is 'nothing in thought which was not first in perception.' The first objection, psychologists meet by pointing out that the error in observation may be small if the time interval be made small; the second objection they unanimously ignore.

I insist that no introspection of this sort is possible. Neither in the moment of its occurrence, nor in any other moment, is the awareness of an awareness possible. And I defy anyone to find anywhere in the literature of so-called experimental psychology an account of anything which can seriously be called such an observation. What is really observed, as set forth in such reports, I shall consider shortly.

Further than this, I claim that neither in introspection nor in any other kind of observation do we find any kind of 'mental' objects, 'psychic' objects, or any content other than such things as are usually called physical objects. So that introspection as the examination of some form of content different from real things, and by nature the private property of the individual, is excluded, along with introspection as the examination of consciousness itself.

Now comes Professor Bode, and accuses me of not being sufficiently and consistently radical. He states that although I take exception to the evidence of introspection in behalf of images, my objection is not based on the ground that this evidence involves a highly questionable assumption, but rather on the ground that *introspection* reveals muscle 'sensation' rather than images. The question I have raised concerning images is, therefore, according to Professor Bode, entirely artificial because it assumes the existence of a psychical existence which conceals its true nature from everyone except an occasional introspectionist. The 'muscle sensation,' of which (unfortunately) I have spoken, is alleged to be just as undemonstrable as the 'image' of the orthodox psychologist. Professor Bode continues the objection by assigning a reason why I make this questionable and damaging assumption. According to him, Professor Lovejoy and myself both ruin our arguments at the outset by postulating a transcendent power of thought. This postulation, it is true, I do make; but as this assumption is not really the source of my hypothesis of muscle-process as thought-content, although it coheres strongly with it; and as I am unable to make out what Bode's objection to the postulate is, I shall not consider it, except indirectly, in the present paper.

The main objection which Professor Bode raises merits careful consideration, for it is the most serious obstacle in the way of explaining my hypothesis to those who hold tenaciously to conservative views. This objection is in the present case founded on my unfortunate use of the word 'sensation'; and on the ambiguity of the concept of 'introspection' which permits the persistent dualist to take in a dualistic sense my

statement meant in quite a different sense; and this whether I use the term 'introspection' or not. If a dualistic interpretation be put on certain of my statements, they of course become inconsistent with my expressed purpose of attacking epistemological dualism.

The charge that I depend too much on introspection, coming from a philosopher of Bode's training is a surprise, but a pleasant one. As a matter of fact, I had been prepared for exactly the opposite charge: that I have based my hypothesis, not enough on direct observation of the facts involved, but too much on physiology. Not that I counted much of my argumentative material as really physiology, but it is the sort of stuff that many persons suppose to be physiological. I am inclined to agree with Bode that my appeal is really in large measure to introspection: not to introspection as it is usually defined, but to introspection as it really is. It is at this point therefore that I may well begin my explication.

Scientific procedure is full of assumptions, explicit and implicit; and the most useful operation is to make the implicit ones explicit. Bode implies an assumption which when made explicit seems clearly infertile. He implies that in dealing with certain contents or objects it is not useful to make a direct examination of the contents themselves. On the contrary, it seems to me a necessary assumption that the scientific study of any contents or objects must start with the observation of the objects themselves, although it must not stop there. A study of Heppelwhite furniture, for example, which avoids examining any of the pieces themselves, is obviously abortive. So any consideration of the vital question as to the reality of a certain hypothetical form of thought-content which does not involve some observation of actual thought-content must necessarily prove futile. The more difficult the observation the less dependence can we place on the result of any single observation, and the more needful is the study of the conditions under which the content seems to arise: but no amount of difficulty in observing renders it permissible to omit the observations.

Let us consider now what can be observed, either in the observation which we call perception or in the observation which we call thought. The observable things in the universe may be classified in various ways, but the most useful procedure is to reduce these facts by analysis to simple or elementary data and classify these. Or at least we may reduce to facts which, if not *elements* in the logical sense, are *radicals*. The classification of the entire system of radical data in four groups is usually considered exhaustive, the four groups being: (1) sentienda or sense-data; (2) relations; (3) images; and (4) feelings or affects. Few psychologists, so far as I know, have claimed the ability to observe anything else. These 'few' include those who, like Professor Calkins, seem to claim that they have observed their own Egos, and possibly should include certain adherents of the imageless thought school who seem to have observed something in German which as yet has not been observed in English.

The objection most generally raised to the classification is that it is unduly extended. Some, like Ziehen, insist that image and sense-datum are in the same class, and others, like Stumpf, seem to classify feeling and sense-datum together. The difficulty in evaluation of these viewpoints is due in part to the fluidity of terms we have above considered and is enhanced by the divergences in range of fluidity between the German terms and their nearest English equivalents.

Restricting ourselves to content for our observable facts our first business is to observe them. When the question arises whether a feeling is merely a sense-datum, we observe specimens of the two classes and compare them. And we observe also complexes in which the two occur, and compare these. We do not merely, for example, compare pleasure with red, we compare a chair with sorrow, and ask if the latter belongs in the same class with the former. These comparisons as usually carried out lead to no consensus of opinion. Some observers report yes, some report no. In a similar way the chair I think of is to be compared with the chair I see. As to the relation between these there is again a difference of

opinion which is large but not necessarily discouraging. Unaided observation, or rather, observation which is not properly complicated, gives in such cases as these some of the truth but not all of the truth, and possibly more than the truth. Some interesting points of agreement come out however: with regard to such a content as hunger, for instance. Some persons localize it: it is as surely, if not as definitely, in the thoracic region of the body as the color of a rose is on the petals. Such persons, from what I am able to ascertain, consider hunger to be as truly a sense-datum as is color or sound. Other persons fail entirely to localize hunger. It is for these persons as general and unspatial as pleasure or interest, and correspondingly these persons class it with the feelings.[1]

Since simple observation brings us to no definite conclusion we must utilize aids. That is to say, instead of confining our investigation to the objects of prime importance we begin to observe objects and processes which may be connected with these other objects in some special way. We turn most usefully to the consideration of the nervous system. We find that the perception of a simple sense-datum depends on the stimulation of an afferent nerve ending.[2] Color is perceived when the rods or cones in the retina are stimulated in a certain way. Flavors are perceived when certain cells in the taste buds are stimulated, and so on. The evidence, such as it is, points to the conclusion that peripheral stimulation is the *sine qua non* of sense perception. If this is the case with sense perception, it is entirely possible that the perception of feeling may result from the stimulation of the nerve endings in the muscles (especially the smooth muscle

[1] This result raises an interesting hypothesis, namely, that the observable characteristic which distinguishes a feeling from a sense-datum is nothing but spatial localization.

[2] Notice that we say the *perception* of a sense-datum depends on nervous action. It is customary, by using the same term (sensation) for both the sense-datum and the perception thereof to pass from the known fact that the occurrence of the *perception* is physiologically conditioned, over to the assumption that the existence of the *datum* is physiologically conditioned. This usage is one of the most fertile of the centers of confusion in psychology and being almost universally adopted has played an important part in the prevention of psychological progress.

which encircles the blood vessels, the alimentary canal, and the ducts of the larger glands) and the endings in the mucous and serous membranes and in the connective tissues: or from the stimulation of certain of these endings.

This is no new point of view. It has been prominent since 1884 when James (then assistant professor of philosophy at Harvard) published his essay on the emotions, although James's theory did not consider the feelings at all but considered merely non-affective factors in the emotions. Lange (professor of pathological anatomy in the University of Copenhagen) published the following year a theory somewhat agreeing with that of James. And it has since become customary to dub either of these theories, or theories resembling them, the "James-Lange theory." Lange and James derived their theories from Darwin's "Expression of the Emotions." Darwin did not arrive at either theory, but his account of the so-called expression of the emotions as a survival of instinctive behavior which was originally useful, would suggest the "James-Lange theory" to any acute physiologist interested in the causes of emotion. As to the general primary condition of an emotion, James is quite clear; it is activity of the bodily tissues—chiefly the viscera—stimulating the end organs contained therein. But as to the fundamental nature of the emotion itself, James is not so clear. Apparently the emotion is the 'state of consciousness' aroused by the process beginning with these visceral endings. But it is difficult to make this out with certainty in view of James's peculiar use of the term 'consciousness.'

Lange is clearer. The emotion *is* the bodily activity or condition. And this is the view the realist must inevitably take. The analogy is perfect between the sensible object which stimulates the retina, or the olfactory membrane; and the muscle contraction, or other tissue change which stimulates the nerve endings in, or adjacent to, the tissue. Moreover, the emotion, since it is an observable object, must be a real thing, or an aspect of a real thing, and not some quasi-object in a realm of 'psychic' pseudo-reality.

Now an emotion, according to the customary interpre-

tation of the 'James-Lange theory,' is not wholly organic sensation (I use the word 'sensation' here because it is customarily used in this connection), but includes certain elements of feeling, such as pleasure and pain. And it is the nature of these elements which we are investigating. James, however, does not reduce the feelings to organic 'sensations.' In fact he has little to say about the feelings, but makes it rather clear that they are not organic 'sensation.' He speaks of them as of *cerebral origin*, meaning that they are primary feelings of the special senses; they are strictly optical, auricular, etc.

When I say that this theory of feelings as organic processes dates from James's articles, I mean merely that it is the obvious development of James's theory, although neither James nor anyone else (except possibly Lange), so far as I know, ever identified feelings with organic processes. Stumpf it is true, insists that feelings are 'sensations'—"accessory sensations"—but apparently this is the same concept which James had with regard to feeling, and has no intelligible reference to an organic or visceral basis.

We must now, I think, go the whole length. Feelings, as well as the non-affective components in emotion, are bodily states or bodily changes. Emotion is not to be considered as made up of bodily 'sensation' *plus* feeling, but of bodily processes *including* feeling. We must follow Lange, rather than James, in making the emotion not a *result* of the bodily state, but the *bodily state itself*. It is true, as James says, that we do not tremble *because* we are afraid: but it is not true that we are afraid because we tremble. The trembling *is* the fear.[1]

The process of substituting a solid reality for the ghostly 'psychic object' begins, then, in the realm of feeling. It might just as well have begun in the realm of thought-content,

[1] Of course, here we are qualifying, as James does. The trembling is not the major feature of the fear; but it is selected to represent the complex because it is easily observed. The visceral changes—in heart, blood vessels, intestines and glands—are the significant parts of this complex emotion: the trembling of the limbs is mentioned as representing the emotions merely because it is the most *readily visible* feature, and we have a tendency, in observing, to emphasize visual observation; as we shall see later.

and wherever it begins it must spread, in the name of consistency and completeness, over both feeling and imagery. We have no more solid reason for continuing the romantic fiction of a world of 'mental images' than we have for supposing a world of purely 'mental' feelings. Nor would this hypothesis have arisen except as a result of a strongly dualistic philosophy. To the poetic genius of Malebranche, and the forensic genius of Locke (who was steeped in Malebranche's theories), we owe the blighting dualism in psychology.

When we simmer down the mass of so-called introspective evidence for 'images,' we find in the midst of the contradictions, this agreement; that in addition to the *absent* content or object, there is a *present* content. When I think of the gilded dome of the Congressional Library, there is involved something more than the dome and my consciousness of it. This something more is what is misrepresented as the '*image*' of the dome.

I shall not dwell on the details which make us doubt the accuracy of the observations which give us account of the exact features of these 'mental images.' I shall merely emphasize the fact that these observations, in spite of their obvious failings, point strongly to the conclusion that something has been observed: that there is something of the nature of present content before consciousness, at the moment of occurrence of thought, and functionally connected with the thought.

What can this content be? Several factors lead us in the same direction. The important parts that so-called 'muscle sensation' and 'muscle image' play in thought processes (ideomotor processes: motor imagery): the presumption that the neural condition of thought-consciousness (like that of sense-perception and that of affective consciousness) begins with a peripheral stimulus: the facts of perception-building and the association of ideas: all point directly and clearly to muscular contractions as the secondary thought-content. And the muscle contractions seem to fit all the requirements of the case.

The differences between my present statements and my earlier attempts to explain my theory of imagination seem worth emphasizing. First, I have abandoned the term 'muscular sensation' or 'kinaesthetic sensation' because it has been persistently misunderstood; and second, I do not insist upon a sharp distinction between immediate (or secondary) thought-contents and feelings. Feeling may involve the action of the voluntary muscle, although its most characteristic factors are probably due to smooth muscle. Thought-content may involve smooth muscle, in cases where 'affective association' occurs, although the more highly specialized thought-content is activity of striated muscle. I shall not now go over the arguments for the muscle-process. That it furnishes a basis (and the only basis which has yet been suggested) for both the building up of perception and for the so-called 'association of ideas,' I believe I have shown intelligibly in my article in the *Circular*. It remains but to make clear my view as to the aspects of the muscle-process presented to consciousness, and in so doing to remove certain specious objections to the hypothesis of flesh and blood feelings as well as to the hypothesis of fleshy 'images.'

If we examine a muscle and its contraction, we find that the contraction may be observed in several ways. First I may *see* it: if my forearm is bared and I clench my fist, I may observe the swelling, and even the shortening, of the muscles of the arm. If I should have the skin and fascia removed from the arm, the muscle action could be observed in still more detail. (For such observations, however, it is customary and more convenient to use the hind leg of a frog.) Now, if I put my finger tips on the muscle, I may perceive through *touch* the same contraction; that is, the perceptual process is initiated through the nerve terminals of the finger tips instead of the nerve terminals of the retina.

The muscular contraction cannot be heard, and I doubt if it could be tasted, although the sarcolactic acid, the production of which is an essential part of the contraction, is gustible. But there is a set of nerve terminals within the muscle itself through which we perceive the muscle contrac-

tion, and this mode of perception we may call *myoesthesis*, as we called the former two *vision* and *touch*. Now when we analyze the sensible muscle into its component sense-data, we recognize the visual, the tactual and the myoesthetic sentienda. And when we go a step farther and call them 'sensations' we are apt to forget that they are really component parts of the actual muscle contraction, and suppose we are dealing with some unearthly 'psychic' elements which have only a conjectural connection with the real muscle. (I use conjectural advisedly, in view of the theories of interaction and parallelism.) Hence we must avoid the term 'sensation' and cling to the fact that, whether through the intermediacy of touch or through myoesthesis, and whether with accuracy or with abominable error, we are truly observing the muscle contraction.

Now we may clear up two points which have not been clear to Professor Bode and others. Observation through myoesthesis, and observation through other somatic and visceral senses may legitimately be called *introspection*, as opposed to *external observations* through vision, touch, etc. The results of this sort of observations, as I have said before, are what we usually find given in accounts of investigation by the 'introspective method.'

Introspection, as I use the term, is no more esoteric or mystical than external observations. That accurate observation through the nerves of the skeletal muscles and of the viscera is more difficult than observations through the optic and auditory nerves, merely makes us weigh the evidence of the former more carefully. No one can legitimately object to introspection of the sort here explained any more than to any other form of observation: unless he would insist on scientific hypothesis being absolutely divorced from observation!

So much for the confusion over introspection. Professor Bode's second point of difficulty concerns the possibility of a feeling or 'image' occurring without being attended to, or without even consciousness of it. This possibility (which is an actuality in a large proportion of cases) is disturbing to

Professor Bode merely because he persists in interpreting the myoesthetic content as a part of consciousness itself. Since the so-called 'muscle-sensation' is no more than, but as much as, a feature of the muscle contraction, its existence does not necessarily involve consciousness thereof. No one can reasonably doubt that contraction of the biceps can be provoked in a patient completely anæsthetized. Why, therefore, may not a similar contraction occur in the case of an individual conscious of other things yet not conscious of that contraction? Certainly there is no proof against it, and such an occurrence is really quite intelligible. Not every afferent current produces consciousness, and not every object is an object of consciousness. It seems to me a reasonable supposition that the clock out in the hall is still existing and is still ticking away although nobody hears it; and an equally reasonable supposition that muscular contraction may occur and not be perceived.

The actual conditions of consciousness are far from being known. I have sketched in another place an hypothesis of the neural circumstances under which an arc-reflex may in one case condition consciousness, and in another case not. This need not be dragged in here, for the general fact is clear that the determination of consciousness by a given stimulus is variable.

It is therefore no mystical doctrine I am propounding when I say that the present content of thought may be overlooked in attending to the ultimate content. I am not, as Professor Bode seems to suppose, falling back on a subconscious mental process, but am outlining a scheme on which this objectionable subconsciousness may be explained away.

To some persons I may seem to be reducing everything to physiology, destroying any possibility of a psychology, as well as dragging in the mire some of the things (emotions) which we are accustomed to value most highly; but it seems assured that it is not on this ground that I shall be most vigorously attacked, but on the ground that my scheme is idealistic or mystical. For the principle of real content for all consciousness involves a real consciousness in which the

ego is cognizant of these contents, and the conclusion that the present content in thought is muscular contraction, does not allow us to stop here, but leads to the further conclusion that thought is a transcendent function which reaches out across the limits of time and space, and even of existence, to grasp its primary object.

There is an objection of Professor Lovejoy's to muscle-process as the present-content in thought which is similar to Professor Bode's objection, but which is not based on a misunderstanding of what I have meant by 'muscle sensation.' I recognize, according to Professor Lovejoy, a class of content accessible to introspection only, 'muscle sensation,' and although I escape dualism I fall heir to all of the evils I allege to be inherent in dualism. "It would thus follow that the epistemological monist may take, with regard to introspection, much the same position as his dualistic opponent; he too may acknowledge the existence of purely introspectible material, in a natural and definite sense of the expression—which for all practical purposes of psychology is the same sense as that in which the term is employed by the representationalist" (p. 67). In the continuation of this argument, Professor Lovejoy insists that my 'muscle sensations' are not spatial and are in all ways as 'subjective' as the images I reject.

The doctrine of a private psychic content has arisen, it is true, because there is an aspect of muscle contraction, and an aspect of organic process generally, which is observable by only one observer. But the difference between the dualistic hypothesis and my hypothesis is world wide. Dualism insists that there are two classes of objective reality: *perceptible content*, which is in the mind of the perceiver, and which, by its nature, is perceptible only to him; and a substratum of *matter* which, if perceptible at all, is perceptible to several persons. Strictly, there is no shared content on a dualistic scheme; our universes are strictly private; I have my private world and you have yours—if you exist at all. Matter is common property in the sense that we share alike the inability to observe it. In strict dualism, there is no possi-

bility of inferring from my content to your content or to you, because there is not a single experienced factor common to both. There is however a 'soft' dualism which, without saying much about it, slips into the scheme a few things which may be perceived by several persons. As the 'soft' dualism is on its road to realism, I cannot consider it necessary to argue with it.

In a world of real things, which can be experienced, we can infer from certain facts now before us, to certain others not before us, but which are associated in past experience with the facts. For example, I can infer that there is a meat in this walnut, though neither I nor anyone else has seen, felt, tasted or smelled it. Is the meat any less physical, any less real, any more 'subjective' as the term is used, because no one has seen it?

Let us take an example closer to the facts we are discussing. Is the calf of John Smith's leg, which is seen only by John Smith, more subjective, in the philosophical sense, than the calf of an athlete who exposes it to the gaze of ten thousand persons? Does one leg differ from the other in order of reality? Is one physical, the other merely psychic? Now why is John Smith's calf private content, and the athlete's leg not? Is not the reason found in the fact that the one is not allowed to stimulate the eye of any one except Smith? If Smith should cut his trousers off at the knee would his calf not cease to be private content?

The comparison between the two objects (calves) as seen, is exactly like that between the athlete's muscles as seen and as perceived through myoesthesis. The contraction of the muscle can stimulate many eyes; it can, because of anatomical limitations, stimulate only one set of muscle-spindles. But if some of John Smith's nerve endings, from his own calf, were transplanted to a muscle-spindle in the athlete's calf, leaving the nerve connections intact, Smith might myoesthetically experience the athlete's muscular contraction.

Knowing therefore that the myoesthetic aspect of muscle is a real fact, of the same order as the aspects I perceive through other senses, I may infer from the fact that my muscle

has this aspect to the fact that other muscles, having all other aspects, have this one also.

In such inferences, I may make mistakes: some nuts, be it remembered, are withered, or have worms inside; but if I made an adequately minute and detailed study of the outsides and insides of many nuts, I should therefore not be mistaken as to the insides of nuts whose external character I carefully observe. I may be mistaken in ascribing feelings and myoesthetic content to certain living bodies; but it is my observation that is at fault, and not any inherent impossibility which prevents the inference from truth.

Now, it is just this argument from the given content to the content which is not given which it seems to me Professor Lovejoy abuses in comparing it with the argument from the idea to the object.

If you perceived *a*, *b*, and *c* conjoined with *d* in one case, you may infer in another case where *a*, *b* and *c* are behaving in the same way as in the first case, that *d* is there also conjoined with them. This is far different from inferring a connection or conjunction which never has been directly perceived to exist, and in which one of the terms is, by hypothesis, imperceptible.

As regards the spatial character of the muscular contraction, it may be pointed out that the kinesthetic aspect is just as spatial as the visible aspect. The muscle-aspect which I perceive kinesthetically is just as truly extensive, and is just as definitely located, as the muscle which I see. It is true that it is not the sole occupant of a given space, but neither is anything else a sole occupant of its space. Is it not the essential condition of a real thing, such as a muscle, that is made up of several elements located cospatially? Do not the color and the smoothness of this table top occupy the same surface? And does not the color of every part of the interior coexist in the same space with other attributes or aspects? The questions of extensity and location must always be decided by appeal to the direct data of observation: in the case of the muscles as myoesthetically perceived, therefore, by appeal to introspection. I can see

no other way of deciding between the older theory, that the myoesthetic object is the only fundamentally spatial content; Professor Lovejoy's suggestion, that it is not at all spatial; and my own conclusion, that it, and other seeming contents, are equally spatial, except by observing the same data carefully with the questions in view. I feel confident that everyone who makes the observation without confusion of stimulus and sentiendum will find the same result.

The most impressive objections to psychological realism are drawn from the consideration of illusion and error. While the points raised by Professor Lovejoy are not strictly relevant to the purpose of the present paper, I may appropriately indicate certain facts which are important in dealing with these matters. I should not claim that observation always gives us the object perfectly, and I do not see that the explanation of this inadequacy is any more difficult for the realist than for the dualist. The dualist's usual explanation, in fact, is nothing more than a restatement of the problem. Dreams, as well as the 'false' imaginings, may be explained as confused thought-consciousness of real objects which were previously perceived, as well as by calling them the perception of unique private contents.[1]

The strongest impulse towards the dualistic statement of error comes, I think, from a common but groundless assumption concerning color vision, which is directly connected with the theory of the 'relativity of sensation' (meaning sense-data). I deny emphatically that there is any such relativity as is usually described. Red is red and blue is blue, and never the twain shall meet! Intensity, extensity, relational setting (including space) may all be relative, but quality certainly is not. This is an important matter: for the structure of dualism is built on the theory of qualitative relativity, chiefly the alleged relativity of visual sense-data. The new realists are hard put to explain how two skeins of worsted

[1] As for the various spatial illusions, I have no present theory which explains them. Is the stick in the water bent, or is it straight as it was before putting it in? Or is it both straight and bent? Is the edge of the razor smooth, as it appears to the unaided eye, or is it jagged as it appears under the microscope, or both? Interesting logical questions, and not necessarily insoluble.

may appear of the same color to one man, and of an entirely different color to another. Possibly the true explanation is far less complicated than some that the new realists have constructed. We may reasonably assume that the colors in the case cited are different in total complexity, but that they contain identical components, which alone are perceived by the color-blind man.

As common sense realists we are certain that other human beings and other animals have feelings, and other organic processes which might be called *images* (if we should disregard etymology). Means are now at hand for determining whether other persons perceive these feelings, and experimental means for making similar determinations on animals may be devised in the future. A social psychology is therefore possible, and a partial animal psychology is possible. A complete animal psychology depends upon the discovering of critical methods. I must confess that this escape from solipsism, an escape managed without illicitly scaling the fences which a dualist builds for himself, is one of the most satisfying results of realism: the contemplation of the external world as real, and as experiencible by many others, puts my *soma* and *viscera* into the conditions properly described as comfort, happiness and satisfaction.

The probability of a dignified and useful compromise between psychology and the theory of subconsciousness is also gratifying. The popular concept of the subconscious is obnoxious to orthodox psychologists because it is applied most often to consciousness; and the existence of consciousness whose prime and only certain reality is reduced to the zero point has always seemed contradictory. But when applied to *content* of thought, the concept is entirely unobjectionable, and its discussion may be valuable.

Let us suppose, for example, a train of ideas which starts from a given point and leads to a certain other point. Normally, the person is very little, if any, conscious of the series of muscular contractions which are essential to the train of ideas. But even if there were consciousness neither of the contractions, nor of the 'absent' or primary content associated

with or corresponding with them, the series of contractions might go on in the same order. Now if the final reflex in the given series does arouse consciousness, it will be of the same thought-content which would be thought of if the complete series had been fully conscious. For example: looking at the tower of McCoy Hall suggests the tower on Gilman Hall; this brings in the thought of the clangorous chimes; next I think of the chimes at Mills College; then of Mrs. Mills, the founder of Mills College; and next the former president of the board of trustees, who is now occupying a chair at Yale. Yale suggests Professor Angier of the psychological department. Now each of these ideas depends in part on a muscular contraction which connects one arc-reflex with another; and if this series of reflexes, or a slightly different series of reflexes, connected by the same contractions, should run off while I am contemplating the McCoy Hall tower, I might find myself, at the moment of turning away from the window, thinking of Professor Angier without having any recollection of intermediate thought-content, for the simple reason that the only contents really involved in the case (the muscular contractions), while they really existed, were potential but not actual contents: they existed subconsciously. Possibly we can account, in these terms, for most of the reported cases of subconscious elaboration without bringing in the mystical hypothesis of 'split off personalities,' or indulging in the meaningless terminology of 'unconscious cerebration.'

Although the problem of interaction is not solved by realism, it is more sharply defined, and the problem as usually formulated, vanishes. The influence of feeling (including will) on bodily action presents no serious difficulty when we realize that the feelings themselves are bodily conditions and processes. The problem of so-called 'ideo-motor action' also is nicely resolved into a phase of the general theory of organic content. Any muscular action can become the vehicle (associate) of any thought. It is natural that the action which brings about a given result should become the associate of the thought of that result, but this is not a neces-

sary condition; almost any action will do. The vigorous warfare which is being carried on against certain theories of ideo-motor action is, I believe, a contest with windmills, and fictitious windmills at that. When the 'mental image,' which has assumed such a rôle in the accounts commonly given of ideo-motor action, is discredited, and the muscular contraction substituted for it, there is no doubt at all as to the place the contraction occupies in the series we call ideo-motor.

I might go on from this point and show how satisfactory is the account of the reduction of voluntary action to automatic action, in terms of the muscle-contraction content; but this is really so obvious, in view of what I have said concerning the subconscious, that I may omit it with economy. Among the other points on which muscle-contraction content has bearing, the most important of all, in my estimation, is the value of the theory as a means of welding together into a satisfactory whole the various parts of psychology, which without such a synthetic theory seems to be a mere heap of junk stolen from the machinery of various sciences. Psychology is indeed a large subject, involving several disciplines which at the present time tend to draw apart. Psychology includes the study of the sentienda (sense-data), of feelings, and of relations; their analysis, comparison, and classification. But this work does not belong to psychology alone, nor is it all of psychology. The study of the behavior of living organisms is also a psychological occupation; but this again is neither the business of psychology alone nor the sole business of psychology. The very fact that the psychological study of behavior is selective; that it is interested in certain phases of behavior; indicates an ulterior guiding principle. In both of these branches of psychology we are interested in those things—contents and processes in contents—which are definitely associated or involved with consciousness. Analytical or objective[1] psychology, and the science of behavior, or praxiology, from a

[1] The use of the term "objective psychology" to indicate the analytic study of the objects of consciousness seems to me more logical than its use as equivalent with psychophysiology or psychobiology.

realistic viewpoint, are the necessary complements of each other, and I do not see how any antagonism between them can be discerned, except such as is read in by dualism. Take away the assumption of an inner world of psychic reality, distinct from the world of perceptible outer objects, and the two disciplines become parts of the same discipline and strive for common goals.

The third business of psychology, the part to which both analytical and behavior psychology contribute, is the study of the mind. At this point the reader may "register surprise" with "business" of detecting an absurd lack of consistency on the part of the author. After kicking the mind out at the door, I welcome it in again at the window. Do not be alarmed: it is not the same mind; it is not the mind which the psychologists have been using as the repository of all perceptible objects, but the mind which they have been striving after in their definitions as the totality of processes of consciousness, which I am willing to admit to the place of honor as the chief subject of the psychologist's study. But here I am exceeding the announced scope of my paper, and so must postpone the consideration of the *mind which can be studied* until the proper occasion arises to argue out the question as to the existence of *consciousness which cannot be studied.*

PHOTOMETRIC CONSIDERATIONS PERTAINING TO VISUAL STIMULI

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SYNOPSIS

Light and energy not identical but behave in a parallel way.

I. PHOTOMETRIC CONCEPTIONS

1. *The Point Source.*—Luminous flux. Intensity of source. Illumination. The inverse square law. Standards of intensity. Deviations from the ideal point source.

2. *Extended Sources.*—Normal brightness as distinguished from intensity of an indefinitely small plane source. Normal brightness and luminous intensity at an angle with the normal. An extended source of finite area and its deviation from the inverse square law.

3. *Reflection*—regular, diffuse and mixed. Coefficient of reflection.

4. *Transmission*—also of three types analogous to those of reflection.

II. VISUAL OBJECTS

Reflectors and transmitters as secondary light-sources and as visual objects.

1. *Brightness* of a perfectly diffusing reflector or transmitter or of a perfectly diffusing radiator is independent of its extent, distance or of the angle from which it is observed. Brightness varies with the angle in the cases of mixed reflection and transmission. Brightness of a perfect diffuser in terms of illumination. Two mathematical ways of arriving at brightness.

2. *Images* as visual objects. Refracted and reflected images. The plane mirror and specular reflection.

3. *The measurement of brightness.*

III. THE RELATION OF LIGHT TO ENERGY

Luminous flux is conditioned by the rate of flow of radiant energy (radiant power). Mean and specific stimulus coefficients. Their variability. The several criteria for equality of lights of different spectra.

INTRODUCTORY

The purpose of the present paper is to put in brief form a statement of some of the fundamental physical conceptions which apply to visual stimuli. There seems to be confusion of thought in regard to this subject on the part of investigators in those branches of biological science which deal with light-effects, evident in the literature and in discussion.

The subject is treated from the point of view of one who is a student of physiological optics and has had the benefit of association with others familiar with the principles and practice of photometry and with the physics of radiation. There is no attempt made to give technical methods further than these can be used in the discussion as concrete examples to make the points clear.

Definitions, terminology and symbols are, as far as possible, made to conform with the Report of the Committee on Nomenclature and Standards of the Illuminating Engineering Society,[1] which is in fact the starting-point of the work.

An important question arises at once. What is light? There can be no light without radiant energy. Yet radiant energy may be present without light. Light cannot therefore be identified with radiant energy without endless confusion. Light in the physical sense, or more properly *luminous flux*, is defined as radiant power evaluated according to its capacity to produce the sensation of light. If there is any objection to this definition it is that it is so worded as to state that luminous flux *is* radiant power. It would perhaps be better to state that luminous flux is the stimulus-value of radiant power in producing the sensation of light.

Suffice it to say at present that as long as radiation of identical spectral distribution is considered, luminous flux and radiant power may be treated as behaving in an exactly parallel way. The distinction between the two will be drawn later.

The conception of luminous flux may be made clearer by an illustration. A radiating body emits energy which travels away from it in straight lines. Under constant conditions the amount of energy leaving the body in a unit time is constant. That is, the power leaving the body is constant. If that power has the property of stimulating the retina and producing the sensation of light the resulting luminous flux from the body is also constant. One more point: if we think of the radiating body as within a closed surface, and neglect the absorption of the medium within,

[1] *Trans. I. E. S.*, VII., p. 723 ff., Dec., 1912.

the power intercepted by the surface is the same whatever the shape or size of the surface may be. Likewise the luminous flux intercepted by the surface is independent of the shape and size of the surface.

Photometrists treat of light sources and the luminous flux emanating from them. It is obvious, from physiological considerations, that light must enter the eye to stimulate the retina; and from physical considerations, that every visual object is imaged upon the retina by light, either intrinsically its own as in the case of a flame or lamp filament, or borrowed directly or indirectly from some light source. Hence it is perfectly possible to treat all visual objects as virtual light sources. It is nevertheless convenient to divide the discussion into two parts, in the first of which a few fundamental photometric conceptions will be discussed. In the second, the optical system of the eye will be introduced and the physical significance of visual objects studied.

I. Photometric Considerations

1. *The Point Source.*—Suppose a minute particle of incandescent matter which radiates equally in all directions. This is equivalent to saying that its luminous intensity, I, is equal in all directions. By definition, luminous intensity (*candle power*, expressed in *candles*) is the luminous flux per unit solid angle subtended at the source, and the statement that the particle radiates equally in all directions can therefore mean only that the luminous intensity is equal in all directions.

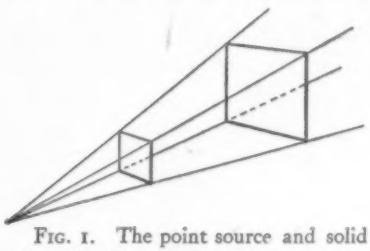

Fig. 1. The point source and solid angle. The light-flux is the same upon any intercepting surface.

It is evident too, that for any small solid angle ω (Fig. 1) the total flux, F, within that angle is the same across any section of it, since radiation travels in straight lines. If this particle is thought of in the center of a sphere of radius r the total flux upon the interior of the sphere will therefore also be the same for any value of r.

Illumination on a surface is defined as the luminous flux-density upon that surface, or the flux per unit of intercepting area.

The flux within the angle ω is $I\omega$. The intercepting area of the spherical surface within that angle is ωr^2. The illumination, E, upon that area is therefore, from the definition, given by the equation:

$$E = \frac{I\omega}{\omega r^2} = \frac{I}{r^2},$$

that is, the illumination is equal to the intensity of the source divided by the square of the distance. This is the well-known inverse square law which is of such great importance to the photometrist.

If instead of a minute portion of the sphere an oblique surface is considered, making an angle θ with the spherical surface, the area of the oblique surface within the solid angle will be larger than the spherical and will be equal to $\omega r^2/\cos\theta$. The illumination upon the oblique surface will therefore be given by the equation:

$$E = \frac{I\omega\cos\theta}{\omega r^2} = \frac{I\cos\theta}{r^2},$$

of which the preceding one is a special case in which $\theta = 0$.

By way of summary a few definitions can now be profitably given, along with the associated terminology.

The standard of luminous intensity is either a flame, produced under certain standard and reproducible conditions, or a particular incandescent electric lamp run upon specified voltage.

The *luminous intensity* of any source is the flux emitted per unit solid angle subtended at the source, and when measured in terms of candles, is its candle-power.

The unit of flux is the *lumen*. It is equal to the flux emitted within a unit solid angle by a point source of one candle, or in other words it is the flux intercepted by a portion of spherical surface whose area is equal to the square of its distance from a point source of one candle situated at its center.

Illumination, on a surface, is the flux per unit of intercepting area. It is of unit value, in the case just described, when the radius of the spherical surface is of unit length and the surface consequently of unit area. The unit may be conveniently remembered as the illumination due to a source of one candle upon a surface at unit distance placed normally to the direction of the flux. The unit of illumination is the *foot-candle* or the *meter-candle* according to the unit of length used. The latter is sometimes called *lux*.

It is to be remembered that no light-source behaves as the hypothetical point source. Standard intensity is obtained from a standard source *only* in a specified direction.

Further, the inverse square law does not practically hold unless certain precautions are taken, as will shortly be seen.

2. *Extended Sources.*—In place of the luminous point just discussed, imagine an infinitely thin and very small incandescent plate. It has a definite area S (Fig. 2) and as a source has also a certain intensity I in a direction toward P, normal to the surface.[1] Other things equal, increase or decrease in the area of the plate will be accompanied by a proportional change in the flux toward P. We can then state that

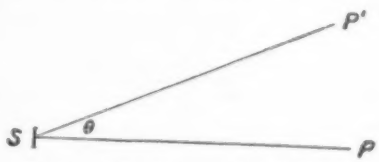

FIG. 2. The element of radiating surface. Its luminous intensity is the product of its *area*, its *brightness* and the *cosine* of the angle between the direction of observation and the normal.

$$I = Sb_0.$$

This introduces a new quantity b_0, the *normal brightness* of the surface S. This is an entirely different quantity from the intensity of S as a source and is on no account to be confused with the intensity. This separation of the two quantities is absolutely imperative where the source is considered as a visual object.

The intensity of such a source in any direction P' other than normal becomes

$$I = Sb_0 \cos \theta.$$

[1] Provided the point P at which I is measured is at a distance very large as compared with the dimensions of S. The reason for this will appear later.

This equation expresses Lambert's law of emission, often called the cosine law, and in general holds true for radiating bodies. It also indicates that practical light sources may have different intensities in various directions.

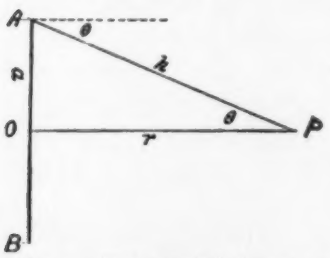

FIG. 3. The extended plane source does not follow the inverse square law.

An extended plane source AB (Fig. 3) examined from a point P, where OP, the normal distance of P, is of the order of magnitude of the diameter of AB, shows a radical departure from the conditions of the ideal point source. The intensity toward P due to a small part dS of the source at O is

$$I = b_0 dS$$

and the illumination upon P due to the same

$$\frac{I}{r^2} = \frac{b_0 dS}{r^2},$$

while the intensity toward P for a similar element of the surface at A is

$$I' = b_0 dS \cos\theta.$$

The illumination at P normal to AP and due to the element at A is then

$$\frac{I'}{h^2} = \frac{b_0 dS \cos\theta}{h^2}.$$

If P is an element of surface parallel to AB it is also oblique to the flux from A, and hence intercepts only a part of it, proportional to $\cos\theta$, and we have then for the illumination on the parallel surface at P due to A

$$\frac{b_0 dS \cos^2\theta}{h^2};$$

putting

$$\cos\theta = \frac{r}{h} \quad \text{and} \quad h^2 = r^2 + a^2$$

we have the illumination on P for an element of AB at A,

$$dE = \frac{b_0 dS r^2}{(r^2 + a^2)^2}$$

and at O,

$$dE = \frac{b_0 dS}{r^2}.$$

From these equations it may be seen that while the illumination at P due to the part O of the surface normal to OP, obeys the inverse square law, the illumination due to other parts (as at A) does not do so except approximately when r is much greater than a.

By integration it is found that if AB be a disc with its center at O, the total illumination at P, normal to OP, is $(Sb_0)/(r^2 + a^2) = (Sb_0)/h^2$, where S is the area of AB. That is, the illumination does not follow the inverse square law but approximates it when r is much greater than a.

3. *Reflection* is of two types, regular and diffuse. In the case of perfect regular reflection, light leaves the surface at an angle equal to that of its incidence on the opposite side of the perpendicular from the point of incidence (Fig. 4).

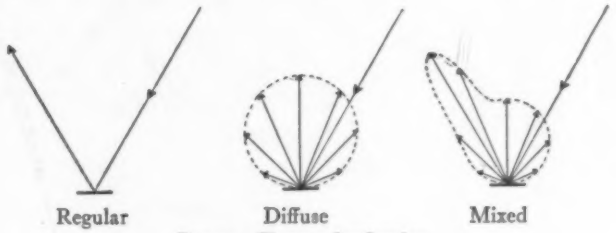

FIG. 4. Types of reflection

In the case of perfect diffuse reflection, light falling upon the reflecting surface leaves it in all directions with exact similarity to the case of a diffusely radiating body, according to Lambert's cosine law (p. 4). Most objects are of a mixed or intermediate reflecting type, part of the light being reflected regularly, although often diffused or spread to a limited extent, and part being diffusely reflected. Any surface which can be made to give a so-called reflection from a window or light-source, and yet reflects more or less light in all directions

however it is lighted, belongs to this class. Examples are numerous—painted walls, most papers, wood-work of a greater or less degree of polish and so on.

Regular and diffuse reflection are only occasionally approximated. A mirror is a typical example of the former, while white blotting paper, plaster of paris or magnesia surfaces approach perfect diffusion.

Measurement of the reflected lights fails to account for all of the light incident upon the surface. A certain amount of it is lost and is said to be absorbed by the surface. The *coefficient of reflection* is the ratio of the reflected to the incident light-flux. We may distinguish between the two portions of reflected light-flux in cases where typical regular and diffuse reflection coexist, as in the case of a piece of glass backed with white blotting paper, and determine the coefficients of diffuse and regular reflection separately.

FIG. 5. Types of transmission

4. *Transmitting bodies* offer a parallelism to the different types of reflection (Fig. 5). A clear glass through which objects may be seen transmits regularly, milk glass scatters the light transmitted through it in all directions approximating perfect diffusion, while a ground or frosted glass diffuses part of the light but transmits a large fraction in directions approximating that of incidence.

This statement presupposes the transmitting medium to be a thin parallel-sided layer. Otherwise refraction enters and modifies the result.

As in the case of reflection there is a *coefficient of transmission* which is the ratio of the light-flux transmitted to the incident flux.

With respect to the coefficients of reflection and transmission the parallelism between luminous flux and radiant power breaks down. This is for the reason that all wavelengths of light are not transmitted or reflected in equal proportion and we are therefore dealing with two radiations of different spectral distributions in the radiation before and after incidence respectively. The same reason applies to the case of luminous flux from two sources of different spectral characters, as from a tungsten and a carbon lamp. The source to which it is referable should always be specified along with the coefficient of reflection or transmission, as it is only by way of exception that the coefficient is the same for two sources of different spectral character.

II. Visual Objects

It is obvious that any reflecting or transmitting medium may be considered as a light-source, having different intensities in different directions, depending upon the character of its reflection or transmission and upon the manner of incidence of light upon it. Visual objects are chiefly objects which reflect light, although intrinsically luminous bodies (light-sources) and transmitting media of various kinds are by no means to be excluded from the list. Even images, which have existence only as particular arrangements of light-flux, have to be reckoned as visual objects. In short, any locus in space from which light-flux enters the eye has to be considered as a visual object or a part of one.

A perfect diffuser, considered from this standpoint, follows the cosine law exactly as a radiating surface does, and such bodies are of especial interest as visual objects.

1. *Brightness* is the photometric quantity that determines the lightness or darkness of the object as a visual stimulus. While this is perfectly true, objects of equal brightness do not always look alike. They may give rise to different sensations. A gray surface may, for example, be made to

appear lighter or darker by slipping (respectively) a black or white background behind it, the brightness of the gray having remained unchanged. The same brightness may undergo similar changes of appearance when viewed (respectively) after light has been excluded from the eye for some time, or after exposure of the eye to very bright environment. These changes are due to modifications in the behavior of the visual apparatus and they are peculiarly referable to the eye itself.

In so far as the lightness or darkness of appearance of any object depends upon the object itself and the light conditions under which it is, the quality of its appearance is determined by its *photometric brightness.*

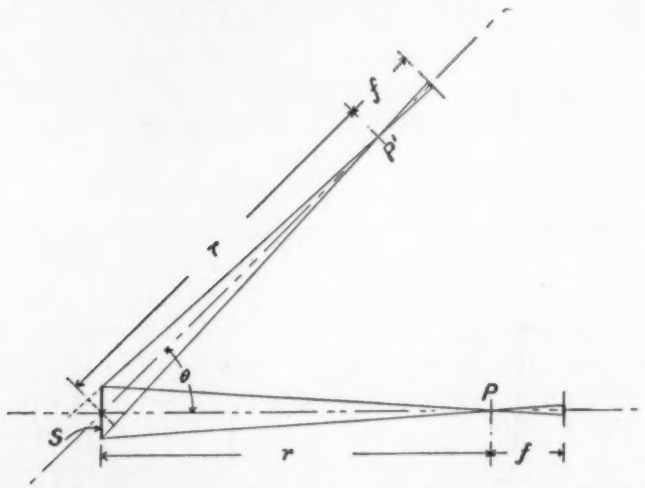

FIG. 6. The photometric brightness of a perfect diffuser determines the illumination of its retinal image independently of the manner of obser vation.

Consider a small surface S (Fig. 6) which may be either radiating, diffusely reflecting or diffusely transmitting. Its intensity in direction P normal to its surface is $I = b_0 S$ as shown previously, and in direction P', $I = b_0 S \cos \theta$ (pp. 6 and 7).

If viewed by an eye at P, the illumination upon the eye due to S is $b_0 S/r^2$ and the flux through the pupil upon the retina $= (k b_0 S)/r^2$ where k is a factor depending upon the pupillary aperture and the absorption by the eye-media.

The area of the retinal image = $(Sf^2)/r^2$ where f is the focal distance of the optical system of the eye. Accordingly the flux-density (illumination) of the retinal image (flux/area)

$$= \frac{kb_0S}{r^2} \cdot \frac{r^2}{Sf^2} = \frac{kb_0}{f^2},$$

which is independent of the distance r and the area of the surface S.

Again, in the direction P' the luminous intensity is $b_0S \cos \theta$ and the flux upon the retina for a perfectly diffusing surface is

$$\frac{kb_0S \cos \theta}{r^2}.$$

The size of the image upon the retina is in this case less than before, owing to so-called foreshortening, and is equal to $(Sf^2 \cos \theta)/r^2$, and the flux-density of the retinal image is

$$\frac{kb_0S \cos \theta}{r^2} \cdot \frac{r^2}{Sf^2 \cos \theta} = \frac{kb_0}{f^2}$$

or exactly the same as when seen from P.

Hence the illumination of the retinal image, that is the light-flux per unit retinal area due to the image, of a perfectly diffusing body is independent of the extent of that body, of the distance from which it is observed, and of the angle made by the line of vision with its surface.

It will be seen by examining the course of reasoning by which this conclusion is reached that it depends upon the fact that the light from a diffusing surface leaves it in such a way that the luminous intensity of any element of the surface in any direction is as the cosine of the angle made by the line of that direction with the normal to that element. It is in fact only exceptional surfaces of which this is true, namely, perfect diffusers, and of them we say that the brightness is equal in all directions. These two facts hold together as just shown, and the uniform brightness for all directions may be directly demonstrated when it is a fact by means of the photometer, which is in its essence no more than an instrument for equating the illumination of two juxtaposed retinal

images. Such a demonstration then proves the cosine law of distribution for the surface examined.

In most cases however we would find by photometric examination that the brightness of the body is different from different angles of observation. This is true of bodies of the mixed reflecting or transmitting type. In such a case we would have shown that the illumination of the retinal image of the surface when examined from the direction P' is not $(kb_0)/f^2$ but something else which, by substituting for b_0 a more general symbol b, we will denote $(kb)/f^2$. By following the preceding mathematical reasoning backward this would give for the illumination upon the eye $(bS \cos \theta)/r^2$, and for the luminous intensity of S in the direction P', $bS \cos \theta$.

By choosing a value of b to satisfy these conditions we have at once a quantity, which multiplied by the projected area of S on a plane normal to the line of observation gives the luminous intensity in that direction; and which is also the photometric quantity referable to the surface itself that directly determines its value as a visual stimulus. It is convenient to note that the brightness b may be arrived at in two ways:

(*a*) *Brightness* in any given direction is defined as the luminous intensity per unit area of the surface projected on a plane perpendicular to the direction considered.[1]

It is only necessary then to know the candle power of the surface, as a source, in the direction considered and divide by the projected area of the surface. The candle power is $bS \cos \theta$, the projected area $S \cos \theta$, and the quotient is the brightness b in candles per unit area.

(*b*) Or the brightness is equal to the normal illumination at a point in the direction considered, due to the flux from the surface in question, divided by the solid angle subtended at that point by the surface. The former is $(bS \cos \theta)/r^2$, the latter $(S \cos \theta)/r^2$, and the quotient b as before.

The brightness of a diffusely reflecting or transmitting body may be computed, knowing the illumination upon it

[1] Provided that the surface is of dimensions negligibly small as compared with the distance to the point of observation. That is, that all parts of the surface are, within negligibly small limits, equidistant from that point.

and its coefficient of reflection or transmission. We have seen that the luminous intensity of an element of diffusing surface is the product of its area, its brightness and the cosine of the angle between the direction of observation and the normal to the surface, that is

$$I = Sb_0 \cos \theta.$$

The light-flux within a small solid angle $d\omega$ in the direction θ is then $Id\omega = Sb_0 \cos \theta d\omega$. The latter part of this expression, $\cos \theta d\omega$, by integration for the entire hemisphere into which the light is emitted becomes π, and the total flux from the surface is therefore πSb_0.

If the illumination upon the surface be E and its reflection-coefficient m the flux emitted must also be equal to EmS and we have the equation: $EmS = \pi Sb_0$, whence $b_0 = Em/\pi$.

The same holds true for a transmitting body if we substitute for m the coefficient of transmission. This presupposes two things: first, we must know that the body is a perfect diffuser, and second, we must know its coefficient of reflection or transmission. In spite of these limitations this formula affords a ready means of approximating the brightness of a surface.[1]

2. *Images* considered as visual objects are interesting as possible experimental stimuli and as affording a convenient means of measuring brightness directly.

The face of a convex spherical lens of say not over 30 cm. focal length, when held at arm's length is seen as filled with

[1] A paper surface with a reflection-coefficient of 80 per cent., having an illumination of 7 meter-candles upon it has a brightness of $(7 \times 0.8)/\pi = 1.78$ candles per square meter, more or less, depending on how closely the conditions approach ideal conditions. Such a rough approximation is of use when, as often happens, the conditions are stated in terms of illumination and we wish to make an intelligent estimate of brightness or *vice versa*.

Since the above was written another unit of brightness has been proposed, the *lambert*. It is defined as the brightness of a perfectly diffusing surface emitting one lumen per square centimeter. On a perfectly diffusing surface of 100 per cent. reflection coefficient the incident light, in lumens per square centimeter, would be numerically equal to its brightness in lamberts. One lumen per square centimeter is 10,000 lumens per square meter or 10,000 meter-candles (lux). One lambert is therefore equal to $10,000/\pi$ or 3,183 candles per square meter; or to 0.3183 candles per square centimeter. As a practical unit the *millilambert* is proposed which is 0.001 of this.

an inverted image of distant objects. If of shorter focal length nearer objects may be distinctly seen in the image and a concave lens similarly used presents a reduced erect image. The brightness of an image so observed is easily worked out from the foregoing considerations.

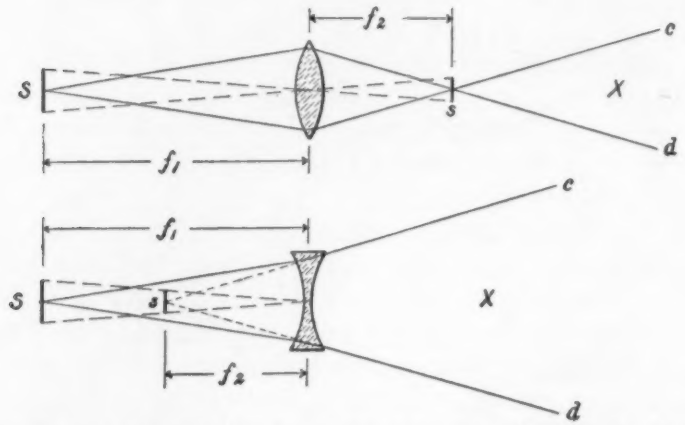

FIG. 7. The brightness of an image directly viewed against a lens-face is equal to the brightness of the object independently of its relative size or manner of observation.

The image s of a small element of the surface S (Fig. 7) sends out light which in effect comes from s to any point lying as X within the angle csd. The flux of the two pencils of light from S and s, limited by the lens aperture, is necessarily equal. That from S passing through the lens aperture whose area is a, is equal to $bS \cdot (a/f_1^2)$ (product of luminous intensity and solid angle).[1] The luminous intensity of s within the limits of the pencil csd is therefore this flux divided by the solid angle csd $(= a/f_2^2)$ and is equal to

$$\frac{bSa}{f_1^2} \cdot \frac{f_2^2}{a} = bS\frac{f_2^2}{f_1^2}.$$

The areas of s and S are as the squares of their respective

[1] The actual pencil of light concerned in vision is not csd but one limited at x by the pupil of the eye. Such a small area of the lens face is used that the error in considering a/f_1^2 and a/f_2^2 to be the respective solid angles is negligible and the relations given hold true.

distances from the lens, therefore,

$$s = S\frac{f_2^2}{f_1^2}.$$

The brightness of s from x is therefore

$$bS\frac{f_2^2}{f_1^2} \div S\frac{f_2^2}{f_1^2} = b.$$

That is, a real or virtual image is just as bright as its object irrespective of their relative sizes or distances.

This of course neglects one factor, the loss of light in passing through the lens. This is constant for a given refractor, a single lens having a transmission coefficient of about 90 per cent.

It will be obvious that the foregoing conclusion applies to the reflected images of the convex and concave mirrors, and to the special case of the plane mirror. The reasoning is exactly parallel. The image is always of a brightness equal to that of the object multiplied by the coefficient of transmission in the case of the refracted image, or by the coefficient of reflection in the case of the reflected image. This applies then to the case of regular reflection, not dealt with in considering the brightness of surfaces. The brightness is in this case referable rather to the image than to the surface.

Regular or 'specular' reflection, as it is sometimes called, often coexists with reflection of the diffuse or what we have here designated as the mixed type. Examples of this are a polished white marble, and a clear glass backed with paper. This of course constitutes another type of mixed reflection. The latter example is mentioned because it shows how the image and the surface-brightness may be concretely added or separated, in exactly the way they would be mathematically considered by the photometrist as two separate brightnesses superposed.

3. *Brightness may be measured* in two ways, either according to its definition, luminous intensity per unit area, or directly by visual comparison with a surface of known brightness.

In the first case suppose the surface AB (Fig. 8) of which o is one point, and a screen at right-angles with op having an opening of area a and placed at a distance r from a photometer p so arranged that from all points of p part of AB is seen completely filling the opening a; and let the distance $op = r$ and the area of AB seen from p be S. The illumination due to AB at p is found by measurement to be E. The luminous intensity of S is then Er^2 which is equal to $bS \cos \theta$ and the projected area is $S \cos \theta$. The brightness is then $Er^2/S \cos \theta$.

FIG. 8. Brightness measured as luminous intensity per unit projected area.

If however the opening a, normal to op is thought of as the bright surface, we have for the luminous intensity of the opening Er_1^2 and its area a. Its brightness is therefore Er_1^2/a which (since from geometrical considerations $r_1^2/a = r^2/S \cos \theta$) is equal to $Er^2/S \cos \theta$.

Hence one actual way to measure brightness is to place a screen with a small opening between the surface and the point of observation, normal to the line of observation, and determine the brightness of the opening, according to definition. The screen may be done away with if AB is of small dimensions and is in perfectly dark surroundings.

This method is however applicable only to objects of over a certain minimum luminous intensity. The majority of visual objects have a brightness so low that the illumination from them upon the photometer screen under the conditions outlined is too low to make photometric comparison possible. In such cases the method of direct comparison gives satisfactory results.

In this method a portion of the surface S (Fig. 9) to be measured is seen from X in photometric juxtaposition with a surface whose illumination can be controlled and known at least relatively—as for example through an opening in a

screen p illuminated from a lamp L at measurable distance. When the position of the lamp is determined which makes p and S equal, a surface of known brightness can be put in place of S and a similar setting made. By knowing the two distances of the lamp from the screen and the brightness of the standard surface, the brightness of the unknown surface may be computed.

The brightness of an image may be measured in an exactly similar way. The image may however be at S, or perhaps

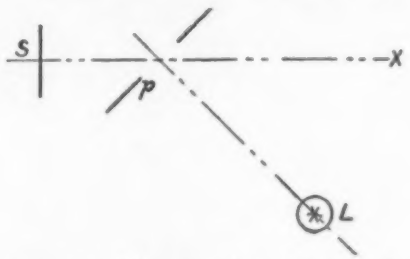

FIG. 9. Brightness measured by comparison with a substituted standard.

more conveniently focused in the opening of p, in either case it must appear from x to fill the opening completely and uniformly.

III. THE RELATION OF LIGHT TO ENERGY

In order that the sensation of light may arise, radiant energy must fall upon the retina. We have seen that brightness, in the photometric sense, is the purely external factor which determines the visual appearance of an object. Photometric measurements are made by making two brightnesses visually equal under conditions equal in all respects, then from the way in which these brightnesses are brought about, computing candle-power, illumination and so on.

Luminous flux is conditioned by the rate of flow of energy. A surface placed normally in the path of light has upon it a certain illumination which multiplied by its area gives the luminous flux that it intercepts. This depends upon the radiant power (energy per unit time) intercepted by it. Luminous flux and radiant power P may be connected by the

simple equation

$$F = K_m P.$$

where K_m is the *mean stimulus coefficient* for the particular kind of radiation used.

For radiation of a particular wave-length,

$$F_\lambda = K_\lambda P_\lambda.$$

K_λ is the stimulus coefficient for the particular wave-length considered, P_λ the radiant power of that wave-length and F_λ the resulting luminous flux.

It is found that K_λ has a variable value for various parts of the spectrum. It rises slowly from zero to a very small value at wave-length 720$\mu\mu$ increasing to a maximum and decreasing again to an insignificant value at perhaps 400$\mu\mu$. Further than this, in any given instance K_λ for identical power conditions varies with different eyes, with the state of the observing eye, and with the brightness at which the photometric comparison is made.

Furthermore, there is still to be settled the point as to the best criterion by which brightnesses may be equated in the case of lights having different spectral distributions, whether by direct comparison, by the so-called flicker method, or by the detail-revealing power of the radiation.

The photometrist, with partial success, avoids this question at the outset, by taking an arbitrary source of radiant energy and assigning to it a certain candle-power, then proceeding, with this as a standard, to measure other sources. In this way he kept out of trouble until he was obliged to compare sources emitting radiation of color (spectral distribution) different from his standard. The fundamentally correct way to make such comparisons is still a matter for discussion and experiment.

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